I.T.E.C.

37 *in weekly parts*

THE HOME STUDY COURSE IN ELECTRONICS AND COMPUTERS

Contents Part 37

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(continued from part 36)

A 4-bit microprocessor

Some of the essential components within a 4-bit microprocessor (an imaginary example) are shown in *figure 2*. This examplemicroprocessor has a 4-bit **data path** (or word size), and so a 4-bit instruction word is placed in the instruction register. These four bits instruct the controller to perform operations on the contents of the accumulator register, in response to signals received from the timer.

The controller is basically a set of

word left over from the previous operation (in this case, 1111), all the lights in the display are off (0000) and the input switches are, for example, set to give the 4-bit code 0101. (Remember, a register can never be empty – it must always contain a 4-bit word, even 0000.)

The timer is initially set to step 0, and we know that the controller performs the instruction held in the instruction register at each step of the timer. With a 4-bit instruction word, it is possible to make $2^4 = 16$ different instructions by setting the instruction switches to the appropriate codes. The total list of instructions is known as the microprocessor's **instruction set**.

2. Some of the essential components within an imaginary 4-bit microprocessor.
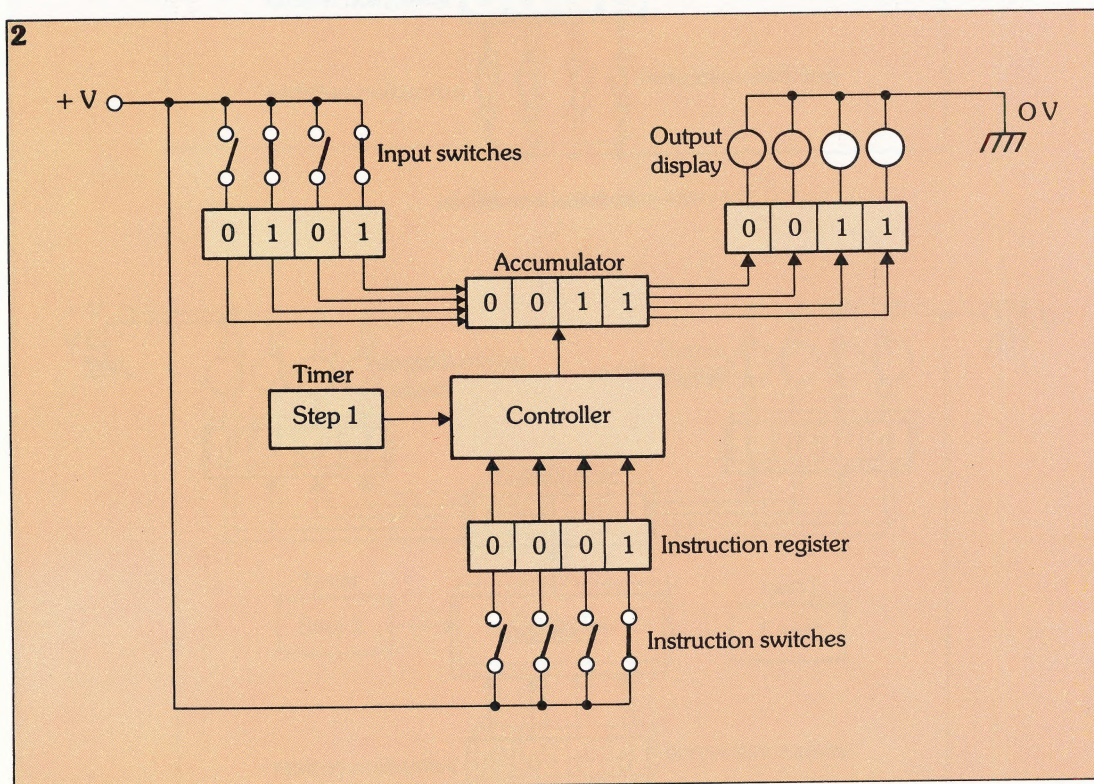
logic gates that controls and manipulates the flow of binary data, according to the combination of bits held in the instruction register. In this example, binary data represented by the input switches can be transferred, on command, to the accumulator, and the contents of the accumulator can in turn be transferred, on command, to the output which is represented here by four lamps.

Figure 3a illustrates the microprocessor's basic operation. To begin with, the accumulator holds the binary

The instruction that we have set in the example is 0100, which we shall define as INPUT TO A. This means that the data at the input is transferred to the accumulator. When the timer sends its first signal (step 1), the controllerdecodes the instruction word and performs the operation. As you can see in *figure 3b,* the instruction has been carried out, and the input word (0101) is now held in the accumulator.

Now, suppose that we want to display the input word at the output. We'll define the instruction 0101 as OUTPUT FROM A,
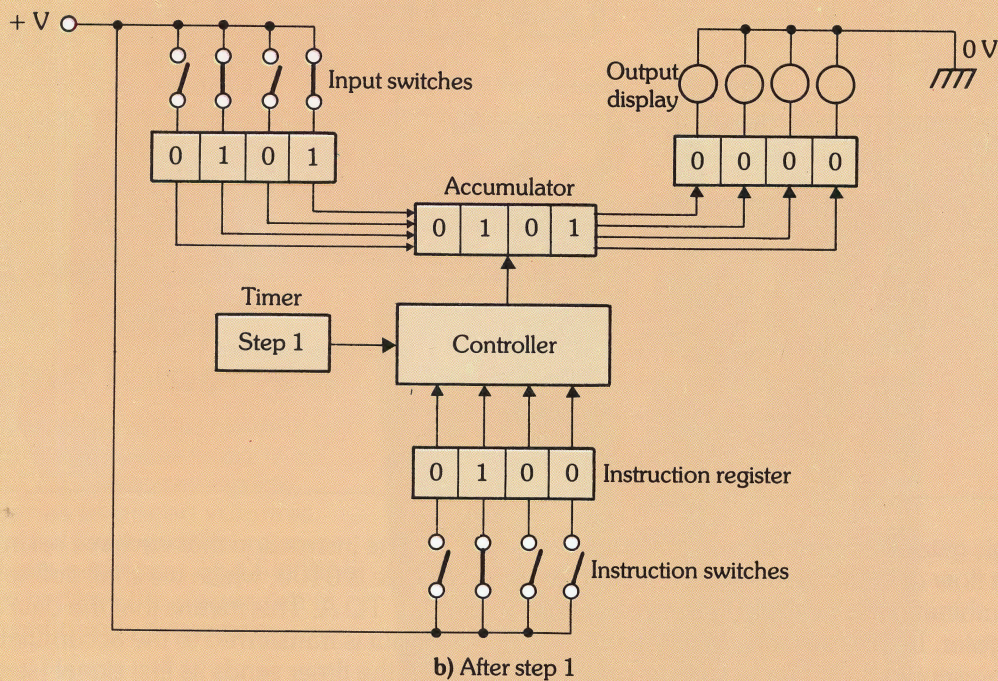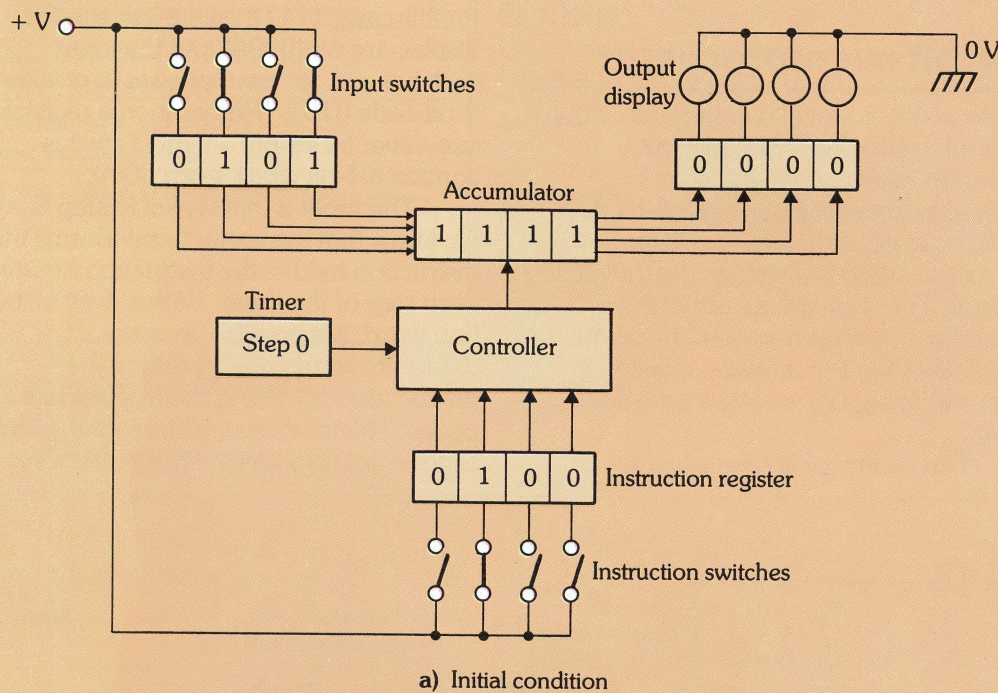
a) Initial condition

b) After step 1

which means that the contents of the accumulator (A) are moved to the output. *Figure 4a* shows that the instruction 0101 has been placed in the instruction register by altering the input switches. When the timer sends its next signal (step 2), the controller decodes this instruction, and the word 0101 is displayed by the output lamps *(figure 4b)*.

As you can see from *figure 4b,* the contents of the accumulator are unaffected by the execution of this instruction – this is
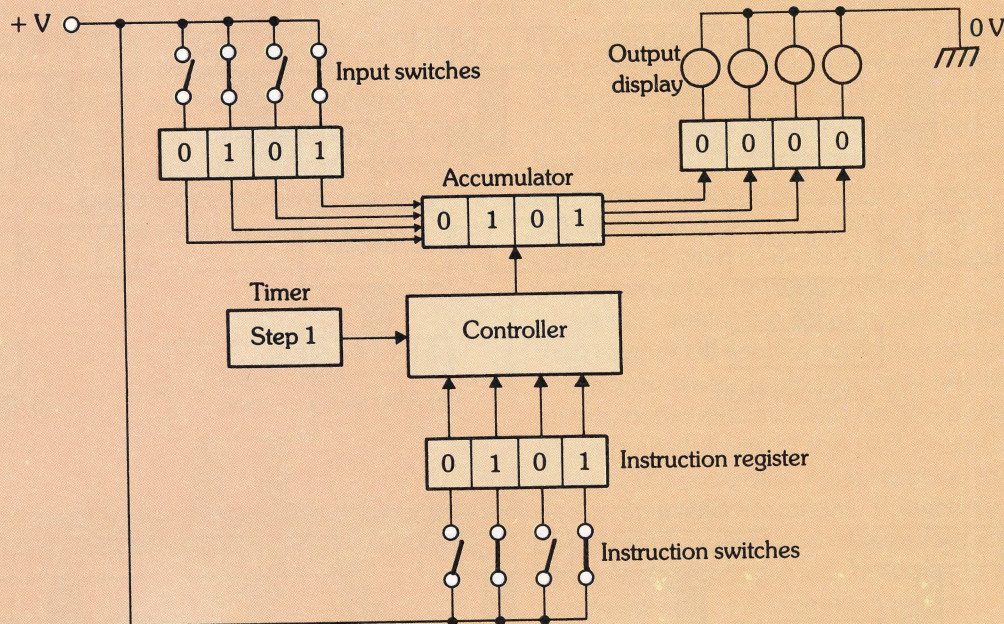
4 a) Second instruction entered
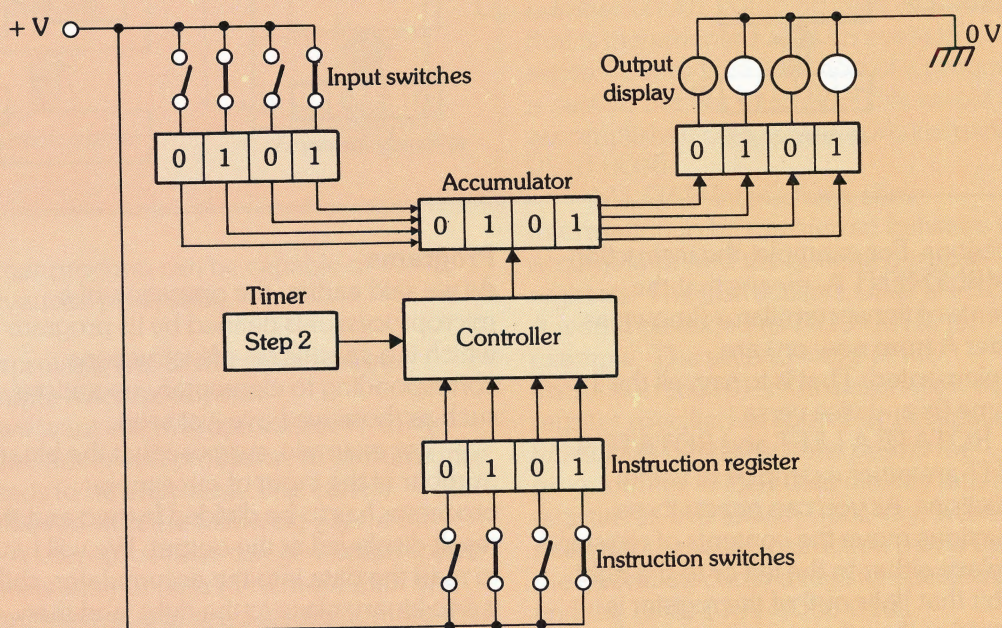
b) After step 2

4.(a) The instruction OUTPUT FROM A (0101) has been placed in the instruction register, and this will transfer the word held in the accumulator (0101) to the output; **(b)** operation completed.

known as a **non-destructive read** of information. Another point illustrated here, is that the same binary word(0101 in this case) can represent both data in the accumulator, and an instruction in the instruction register. It has a separate meaning in each case.

As well as simply transferring data, the controller is, of course, capable of manipulating the accumulator's contents, and these manipulation processes enable the processor to carry out arithmetical

a) Initial condition

Input: `1 1 0 0` Output: `W W W W`
A: `Z Z Z Z`
Step: `0` → Controller
`0 1 0 0` IR

b) After step 1

Input: `1 1 0 0` Output: `W W W W`
A: `1 1 0 0`
Step: `1` → Controller
`0 1 0 0` IR

c) Ready for step 2

Input: `1 1 0 0` Output: `W W W W`
A: `1 1 0 0`
Step: `1` → Controller
`0 0 1 1` IR

d) After step 2

Input: `1 1 0 0` Output: `W W W W`
A: `0 1 1 0`
Step: `2` → Controller
`0 0 1 1` IR

e) Ready for step 3

Input: `1 1 0 0` Output: `W W W W`
A: `0 1 1 0`
Step: `2` → Controller
`0 1 0 1` IR

f) After step 3

Input: `1 1 0 0` Output: `0 1 1 0`
A: `0 1 1 0`
Step: `3` → Controller
`0 1 0 1` IR

operations. For example, the instruction COMPLEMENT A, means that the contents of the accumulator (known as register A from now on) are complemented. That is to say, all the 1s become 0s and vice versa.

ROTATE A LEFT and ROTATE A RIGHT are other examples of useful instructions. As you can guess, these instructions move the contents of register A one place either to the left or to the right. The bit that 'falls out' of the register is replaced at the other end, because there are only four available places. Shifting 1001 to the left gives 0011; while shifting it to the right gives 1100. The accumulator is thus made to act as a **shift register** with what is known as an **end-around loop**.

These operations have the effect of either multiplying or dividing (shifting to the left and right, respectively) binary numbers by two.

Programs

As we said earlier, the operation of a microprocessor is defined by its program which is a specific set of instructions corresponding to elementary operations, such as those we have just seen.

For example, suppose that the binary number at the input of our simple processor has to be divided by two and the result displayed at the output. We will have to read the data into the accumulator, shift it one binary place to the right, and then move the answer to the output. These three steps can be turned into the following program:

Step	CODE	INSTRUCTION
1	0100	INPUT TO A
2	0011	ROTATE A RIGHT
3	0101	OUTPUT FROM A

The stages in the execution of this program are illustrated in *figure 5*. The lamps and switches have been discarded

5. Stages in the execution of a program that reads in a number, rotates it one bit position to the right, and writes it as output.
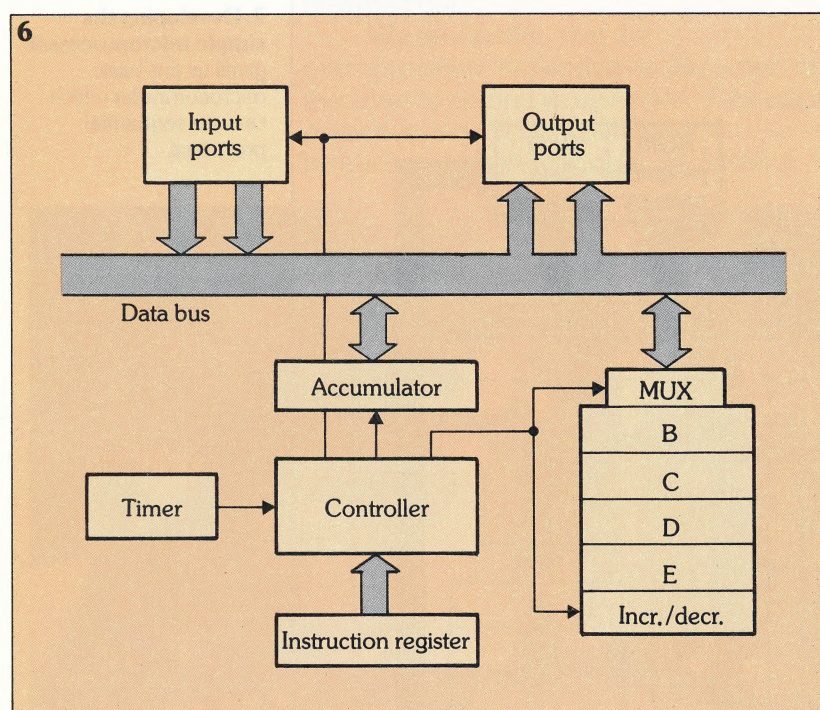
for clarity (and so the input, output and instructions are now just shown as the contents of their registers). The wires are now shown as **busses**. The numbers ZZZZ and WWWW are the initial irrelevant contents of the accumulator and output registers. Although this example is very simple, the concepts involved are very powerful, and when applied as part of a

6. Improving the simple microprocessor, with the addition of a bidirectional data bus, general purpose registers connected via a multiplexer and a larger instruction set.

larger program can be capable of advanced processing.

Improving the performance of our simple microprocessor

If we want our microprocessor to solve more advanced problems, its performance needs to be improved. This can be achieved with the following (*figure 6*):
1) A microprocessor can generally receive information or data from more than one input device, and send results to more than one output device. To do this, each device has to be connected to a separate input or output **port**, identified by a number. For example, the two-word instruction 0100-0101 might mean INPUT TO A FROM PORT 5. So, in all input/output operations, the word following the instruction word specifies the relevant port.
2) To transmit information to and from the multiple I/O ports, a **bidirectional data**

bus is needed. This is a common path made of four wires (for a 4-bit microprocessor) in parallel, which is used to transmit 4-bit words in either direction.
3) Some general purpose RAM registers (B, C, D and E in *figure 6*) connected via a **multiplexer** (MUX) to the data bus provide convenient storage for data used in calculations or program control. The contents of each of these registers can also be incremented or decremented. However, unlike the accumulator register, they cannot be used for data manipulation. The accumulator is also the only register able to communicate with the I/O ports.
4) To make full use of this (still simple) system, the controller must respond to a wider range of instructions. Previously, we could input, output and manipulate data. More versatility is gained, however, if we can make use of three new types of command:

a) INCREMENT/DECREMENT instructions are useful for counting. A register, say B (designated by the code number 0000), could be used as a counter that is incremented after an event in a series — every time a section of a program is carried out, for example. This would be accomplished by the two-word instruction 0110 0000.

b) LOAD instructions allow information to be transferred between the accumulator and the general purpose registers. The instruction LOAD D FROM A would be coded as 1010-0010, for example. The second word of the instruction (0010) is the designation of the register specified as source or destination. LOAD DATA instructions permit the programmer to load data directly into a register. LOAD B with 0101 say, would need a three word instruction made up of the operation code, a register specification, and the data: 1101-0000-0101.

c) Logic instructions, such as AND, OR and XOR, allow the contents of the accumulator and register to be operated on, bit by bit; the arithmetic ADD operation is also included. Using this, the contents of a register are added to the accumulator, where the result is stored. Subtraction is easily accomplished by adding the two's complement of the subtrahend.

Storing the program

As you can imagine, the microprocessor only really begins to be valuable when it is given a memory in which to store its program. The processor is then able to fetch instructions from memory, decode them, execute those instructions, and make the results available at the relevant

easily see how a customised digital system can be made.

As you know, a memory is a set of locations where binary information is stored: a 64-bit memory, for example, could be divided into sixteen 4-bit words where each word location is identified by a 4-bit address. If the program instructions

7

Data Bus   Address Bus

Input ports   Output ports   ROM program memory   RAM data memory

Accumulator   Flags   MUX   B   C   D   E   PC

ALU   Instruction register   Incr.

Clock   Timing and control   Microprocessor

7. Developing the simple microprocessor gives us this basic microcomputer which can run sequential programs.
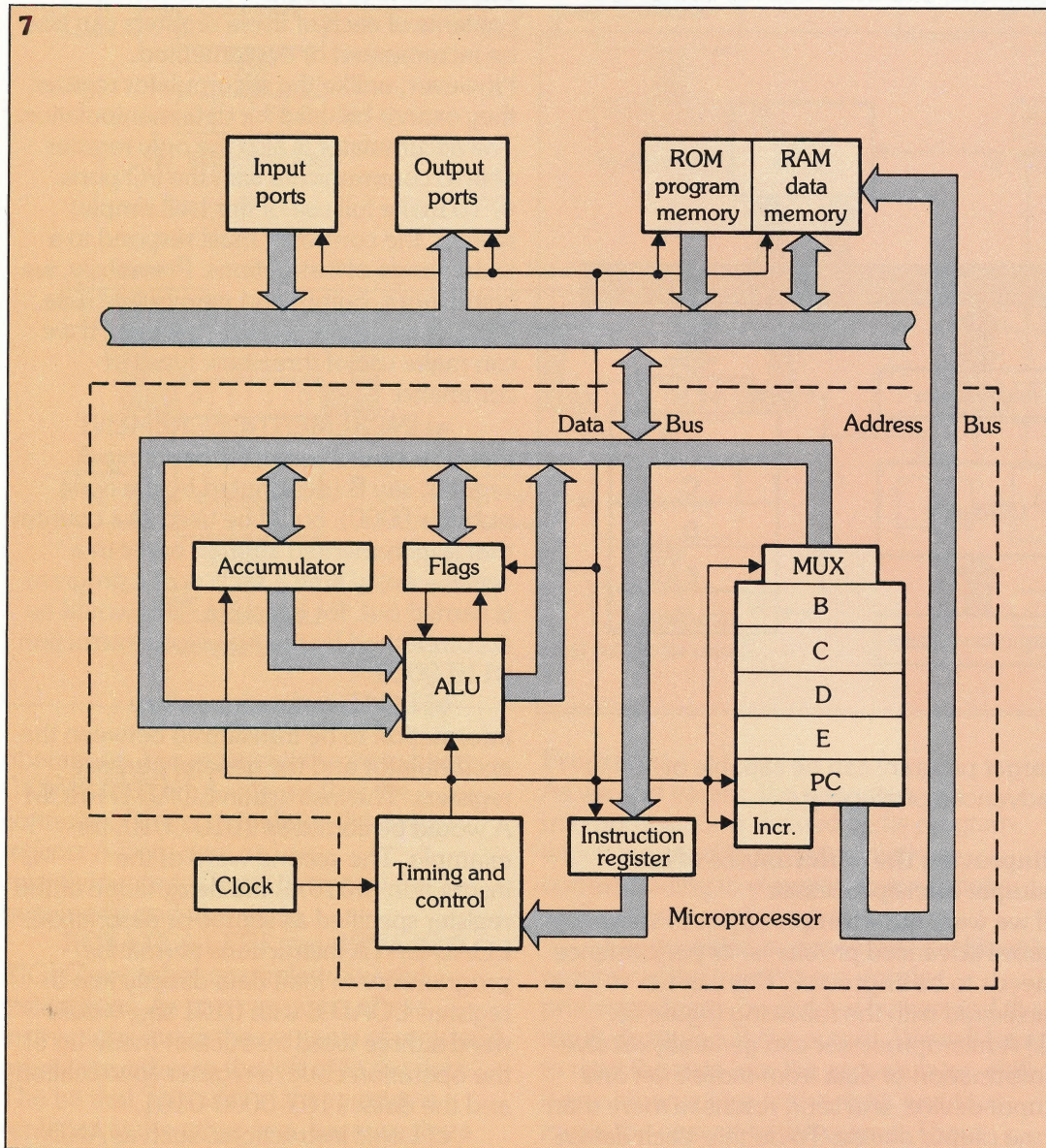
output ports.

Modern manufacturing techniques mean that the instruction decoder, controller, accumulator, auxiliary registers, timing circuits and I/O buffers can be made on one chip. If the mass produced processor is provided with a tailor-made program stored in memory, then we can

are stored in successive memory locations, then the next address is simply the present address plus one.

However, more complex systems exist that depend on more involved search algorithms. In the case of the customised digital system mentioned above, the program would be stored in a form of a

programmable read only memory (PROM).

In a microprocessor-based computer system, for example, where the program was input by the user and often changed, instructions are held in RAM. The address of the next instruction to be executed is held in the program counter register (PC) which is updated each time an instruction is carried out.

We saw earlier, that the microprocessor depended on the action of the timer to control its operation. Processor operation is cyclical – fetching an instruction, transferring data, performing

As you can see, an **ALU** (arithmetic and logic unit) and some **flags** have replaced the controller. The ALU performs all the arithmetic and logic operations needed in the system and has the ability to raise flags to signal certain conditions. Zero, carry and sign flags indicate whether the result of the last instruction is zero or not zero, whether it has generated a carry, or if it is positive or negative.

Another substantial refinement lies in the fact that, until now, we have only been able to run sequential programs. With the program counter to instruct the microprocessor where the next instruction
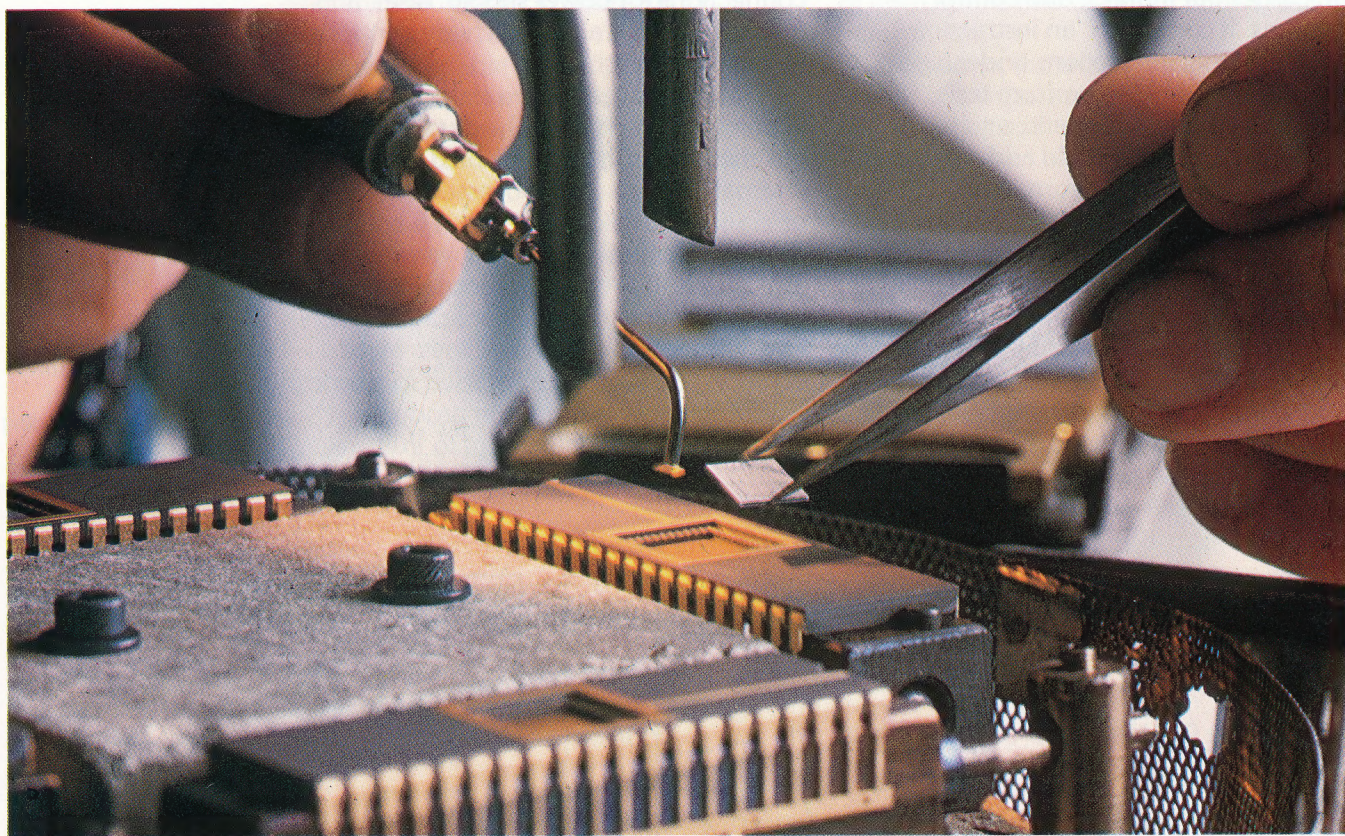
Above: A stage in the manufacture of the Z8000 microprocessor. The metallized ceramic chip support is fixed into the package.

an operation, writing the result, fetching the next instruction, and so on. So you can see that precise timing is needed to synchronise the microprocessor's many operations. This is, of course, provided by a clock via the timing and control circuitry.

A basic microcomputer
A comparison of the basic microcomputer shown in *figure 7* with our simple 4-bit microprocessor in *figure 6* illustrates the way that in which it has developed.

is stored, JUMP instructions can be utilised to literally 'jump' to an other part of the program that is out of sequence.

Jump instructions alter the contents of the program counter to cause the microprocessor to jump. They can either be used conditionally (to jump to another part of the program if a certain condition is met), or unconditionally (as in a loop, where a part of the program is to be run over and over again). JUMPS enable decisions to be made within programs.

Defining a microprocessor

Having now examined the basic building blocks that make up a microprocessor, and looked at the way in which they act together, you'll no doubt have noticed some similarities with the calculator system discussed in earlier *Digital Electronics* chapters. But we can now arrive at a definition of a microprocessor that is more precise than the idea of a 'universal chip'.

A microprocessor is a single integrated circuit that executes instructions and carries out monitor and control functions. It comprises: an instruction register to hold instructions under execution; an ALU to perform tests, comparisons and arithmetic; and additional registers to hold addresses, input and output data, and information concerning processing status. Some microprocessors also have internal clock circuits to synchronise operation, while others rely on external timing circuitry.

Small amounts of RAM (registers) are also used to hold transient data produced in processing, such as intermediate results produced from arithmetic operations, and

the addresses of locations in external memory that are to be used in immediate processing.

The microprocessor's external interfaces consist of an **address bus** that is used to select locations in the external memory chips; a **bidirectional data bus** on which data transfers are made to and from the memory chips and (possibly) devices such as floppy disk units; and a **control bus** – comprising both input and output control lines – that is used to synchronise the microprocessor's operation to that of the external circuitry.

Microprocessors also have connections for power supply, reset, and function select – all of which are controlled by external switches.

Microprocessors are classified according to the size of the data word – the number of bits that can be held in their internal registers and processed in one operation. For example, 4, 8, 16 and 32-bit devices are commonly available. The simplest, 4-bit microprocessors, are used in relatively simple applications such as domestic appliances and toys. More complex, 8-bit devices are used to perform a wide range of functions in products ranging from test equipment to fruit

8.(a)Pinout of the Intel 8008, 8-bit microprocessor; **(b)** corresponding block diagram.

a) Pin-out

b) Block diagram
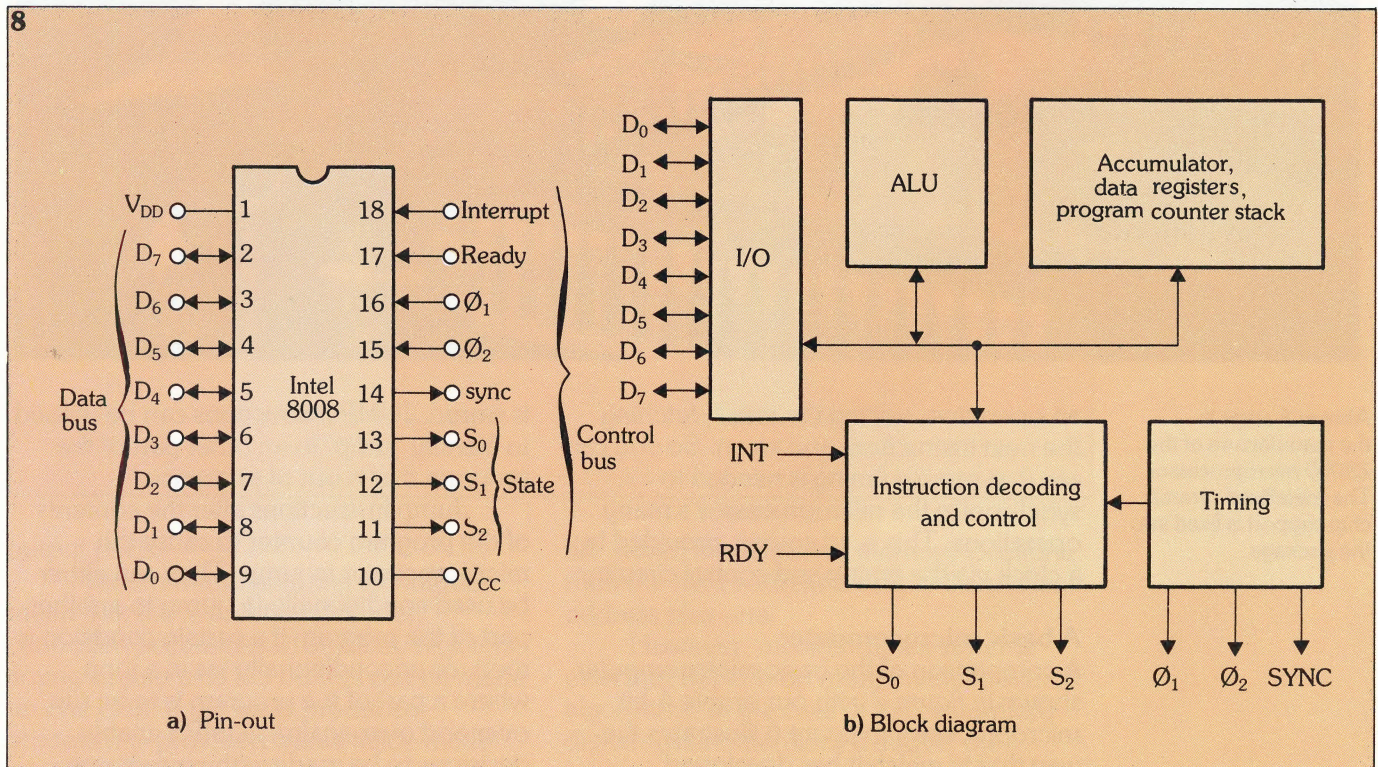
machines.

We must not forget microprocessor-based computers of course, which can use 8-bit, 16-bit or 32-bit microprocessors. The most complex, 16-bit and 32-bit microprocessors are used in similar but more sophisticated applications than the 8-bit chips, and also form the basis of many complex minicomputers.

As we said earlier, microprocessors cannot function alone and must be connected to other building blocks via the relevant auxiliary circuitry. The pinout of a basic 8-bit microprocessor (the Intel 8008) is shown in *figure 8a*, while its block diagram is illustrated in *figure 8b*.

So we can see that a microprocessor is basically capable of the following:

1) Recognise external 'on/off' binary conditions, and receive information in coded digital form.

2) Perform tests and comparisons on input and stored data in order to take action on their outcome.

3) Receive and hold in its memory the instructions (groups of bits) that are needed to make it perform tests and perform input and output operations.

4) Receive and hold in memory the values to be used in tests and comparisons, and patterns of bits that represent characters that are transmitted.

5) Make data transfers to and from other devices and within itself.

6) Manage and synchronise the execution of instructions and the input and output of information.

7) Provide output in the form of binary signals to control equipment, or as groups of coded bits.

Glossary

address bus	the lines of communication between a microprocessor and external memory: used to select locations to read data from and write data to
control bus	comprises input and output control lines which synchronize the microprocessor's operation with that of the external circuitry, e.g. read/write controls, timing signals, I/O selection
data bus	collective term for the lines carrying data to and from a microprocessor
data path width	the number of input or output lines on a microprocessor – defines the word size
instruction set	the set of different possible instructions in the instruction register, e.g. for a 4-bit microprocessor this is $2^4 = 16$, and for an 8-bit microprocessor this is $2^8 = 256$
non-destructive read	a read operation that leaves data in a state in which it can immediately be read again
port	an interface by which data leaves and/or enters a microprocessor

ELECTRICAL TECHNOLOGY
Fourier series

Until now, we have looked at the behaviour of networks supplied by sinusoidal waves and the effect that varying the frequency of the waves has on the circuits. However, pure sinusoidal waveforms are actually very rare in the range of real signals encountered in the world. This creates a problem, as we do not have any method that can be used to analyse circuits working on these sorts of waveforms.

However, a solution to part of this problem was provided by the french mathematician Jean Fourier, who showed that any repetitive wave can be expressed as the sum of a series of sine and cosine waves, known as the **Fourier series**.

Let's start by taking the mathematical form of the Fourier series and then we shall go on to look at its practical significance. If we assume that we have a periodic wave f(t), which repeats after a time T, then we can express it as:

$$f(t) = a_0 + a_1 \cos \omega t + a_2 \cos 2\omega t + a_3 \cos 3\omega t + \ldots + b_1 \sin \omega t + b_2 \sin 2\omega t + \ldots$$

where the two series of sines and cosines continue to infinity. Also:

$$\omega = \frac{2\pi}{T} = 2\pi f$$

Notice that the frequencies of the various sine and cosine terms start at the fundamental frequency, f, and continue with the second harmonic 2f, third harmonic 3f and so on and that at each frequency, there is a cosine term whose magnitude is given by $a_1, a_2, a_3 \ldots$ and a sine term of magnitude $b_1, b_2, b_3 \ldots$ There is also a constant term a_0, which represents the steady, DC component of the waveform.

In the majority of complex waveforms, the magnitudes of the components decrease with higher harmonics. As a consequence, we may usually consider a Fourier series of terms

1. The triangular wave shown here can be broken down into a Fourier series of component waveforms. Only odd harmonics of the sine waves exist.

1

Sum of first three odd harmonics, f(x)

0.81 $\sin \omega_o t$

−0.09 $\sin 3\omega_o t$

0.03 $\sin 5\omega_o t$

f(t)
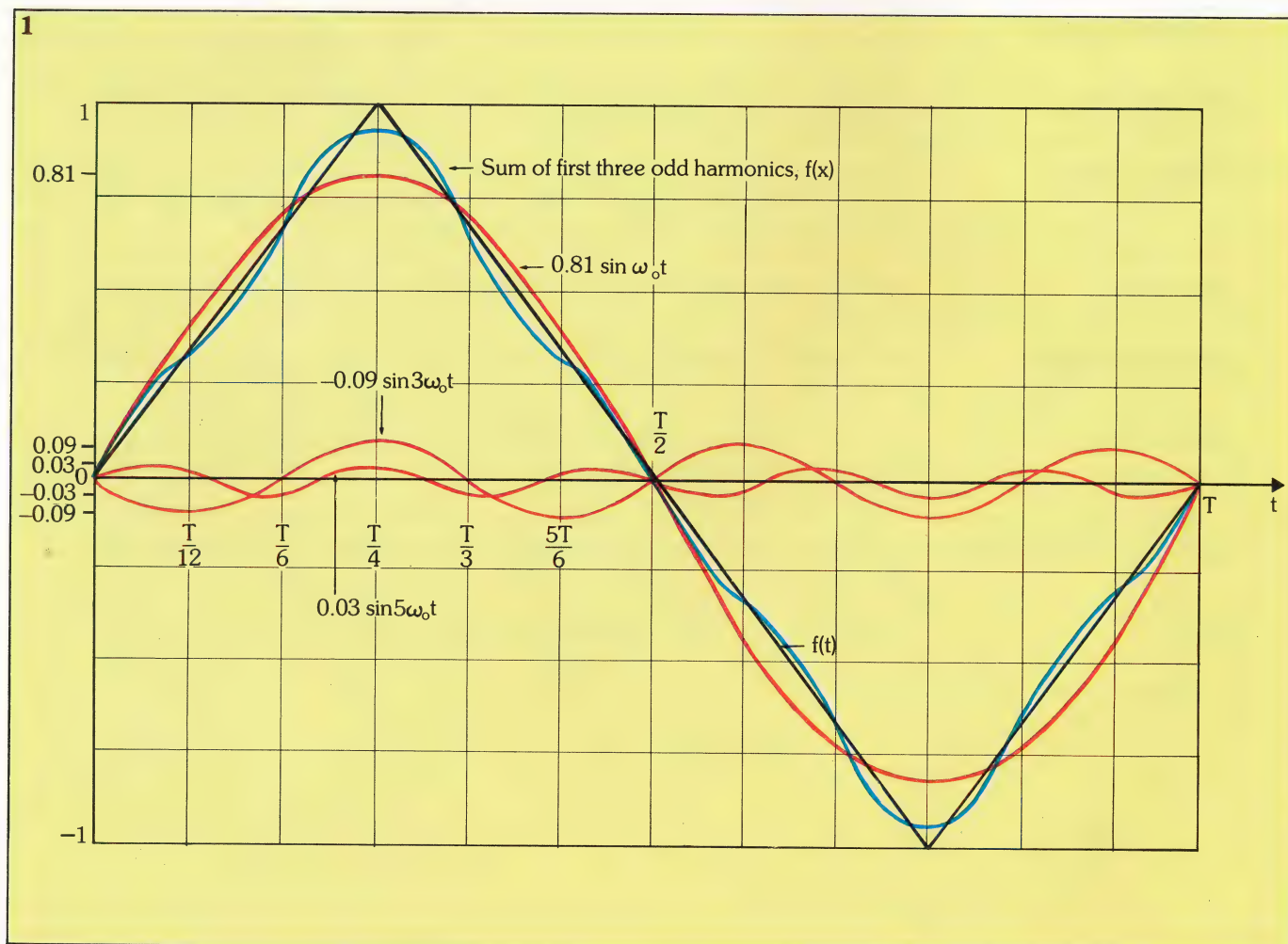
2
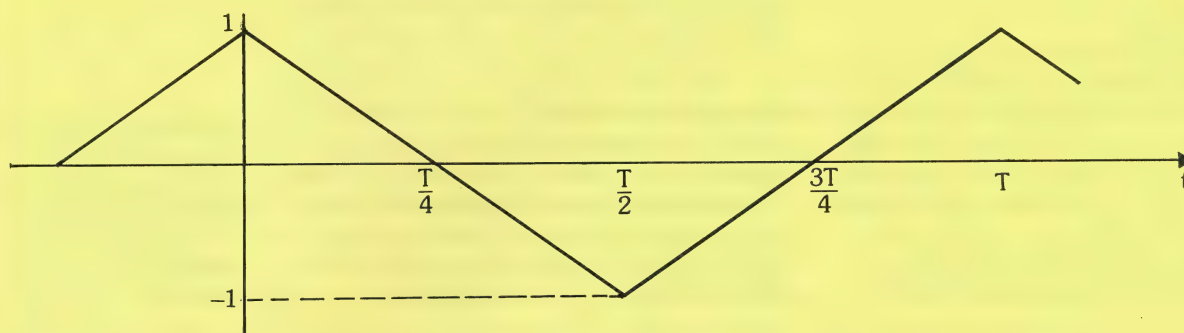
2. Shifting the time origin of the triangular wave to the right gives us this waveform. Here, only cosine terms of odd harmonics exist.

Right: A signal probe is used to examine a circuit's action on the waveform injected.
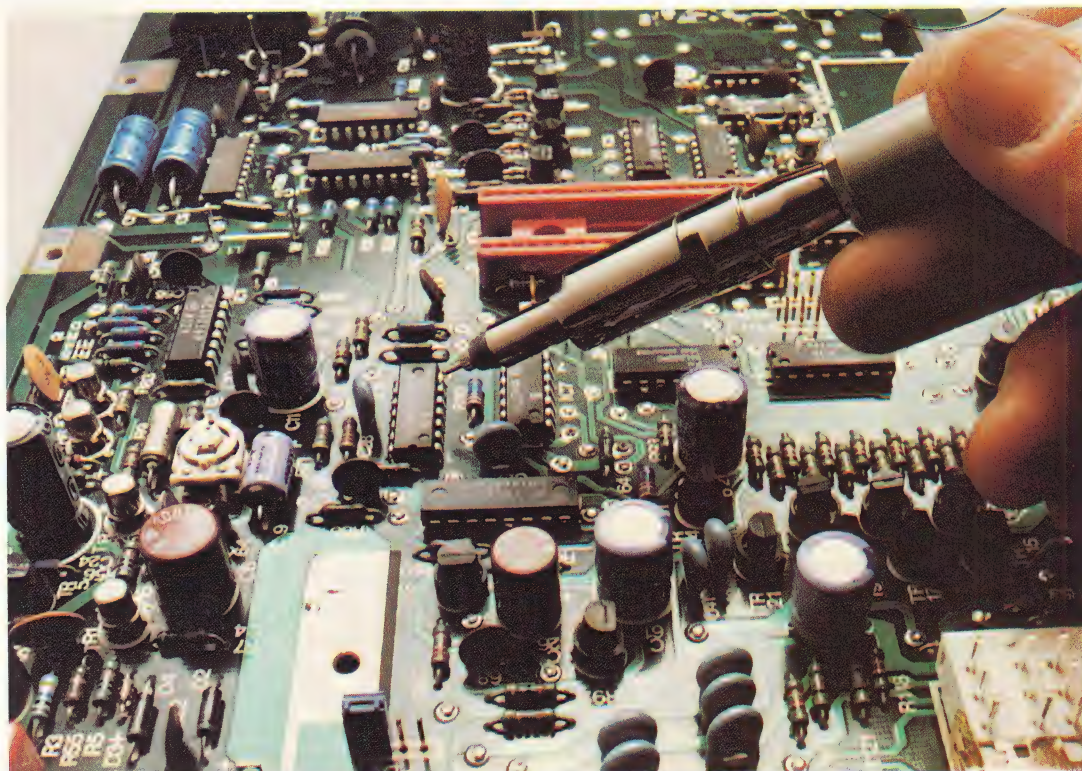
to be of finite length, within limits of approximation.

Consider a simple example: the triangular wave f(t), shown in *figure 1* having a period T, a value of 0 when t = 0 and a maximum value of 1. The Fourier series for this contains only sine terms: the coefficients a_0, a_1, a_2 . . . being equal to zero. In addition, only *odd* harmonics of the sine waves exist (i.e. b_2, b_4, b_6 . . . are all zero). We shall see why so many components of the series are zero shortly. So, the first few terms of this series are:

$$f(x) = 0.81 \sin \omega t - 0.09 \sin 3\omega t + 0.032 \sin 5\omega t - 0.016 \sin 7\omega t + \ldots$$

The first three terms of this series are shown by the three red curves of *figure 1* and the sum of these three components is shown by the blue curve. Even with only three terms of the series this is a close approximation to the triangular wave.

As we are dealing with a periodic wave, the time which we call t = 0 is arbitrary. In *figure 1* the wave is shown passing through zero and increasing at t = 0. If we shift the time origin to the right by T/4 so that it occurs at the maximum, we get the waveform in *figure 2*. The series which represents this is given by:

$$0.81 \cos \omega t + 0.09 \cos 3\omega t + 0.032 \cos 5\omega t + 0.016 \cos 7\omega t + \ldots$$

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Notice that in this case only *cosine* terms of odd harmonics exist.

Symmetry of waves

If we consider the wave shown in *figure 3a*, for values of t from negative to positive, we see that the magnitudes at all negative values of t (say, at $-t_1$) are the same as those at identica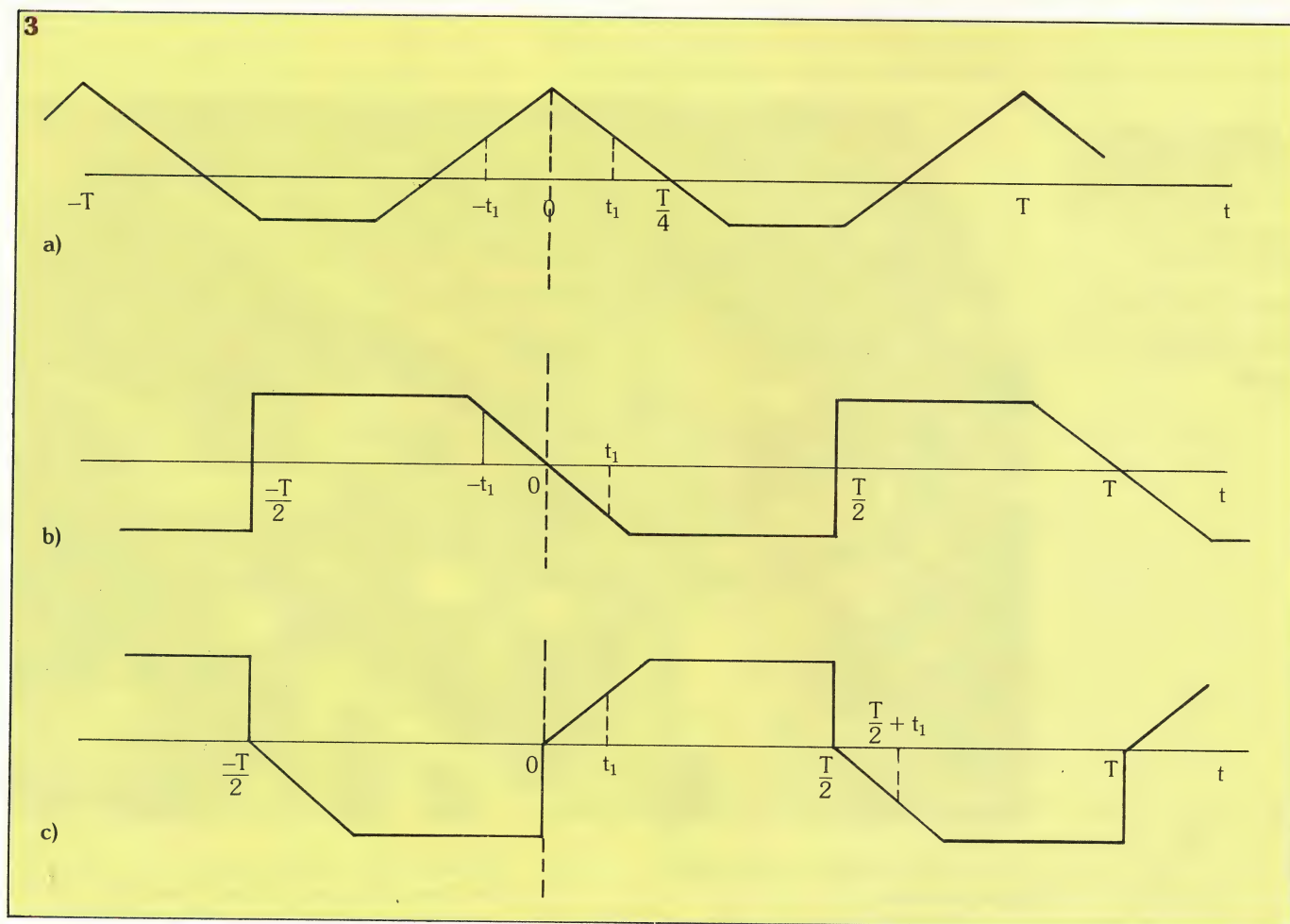l positive values (at t_1). Such a wave is **symmetrical** about t = 0, and its Fourier series contains only cosine terms (all b_1, b_2 . . . will be zero). This is sometimes termed **even symmetry**.

In *figure 3b* we have drawn a different

instant of time t_1, is the negative of the value at time $T + t_1$. This is called **half-wave or rotational symmetry** and the Fourier series representing this function contains only odd harmonics of both the sine and cosine series.

If we reconsider *figure 1*, we see that the triangular wave shown has half-wave symmetry and, if we were to continue the wave to negative values of time, is also antisymmetrical. It therefore must have a Fourier series which contains sine terms of odd harmonics only. Similarly, *figure 2* is the same waveform but shifted in time so it also has half-wave

3.(a) Waveform that is **symmetrical** about t = 0; (b) waveform that is antisymmetrical about t = 0; (c) half-wave or rotationally symmetrical waveform.

wave, in which the magnitudes at negative values of t are the same as those at positive values, but opposite in sign. Such a wave is **antisymmetrical** about t = 0 and its Fourier series will contain only sine terms (a_0, a_1, a_2 . . . are all zero). This is sometimes termed **odd symmetry**.

A wave which is neither symmetrical nor antisymmetrical, on the other hand, contains both sine and cosine terms. This leads us to one further type of symmetry, which is shown in *figure 3c*. Here the magnitude at some

symmetry but it is now even symmetrical, and so its Fourier series must contain only cosine terms of odd harmonics. These results are, of course, as we stated.

Fourier series of a square wave

A square wave is shown in *figure 4*. The Fourier series representing it is:

$$1.273 \sin \omega t + 0.4244 \sin 3\omega t + 0.2546 \sin 5\omega t + 0.1819 \sin 7\omega t + . . .$$

The first three terms of this series are drawn in

4

1.273 sin ω_ot — Sum of first three odd harmonics

0.4244 sin3ω_ot

0.2546 sin 5ω_ot
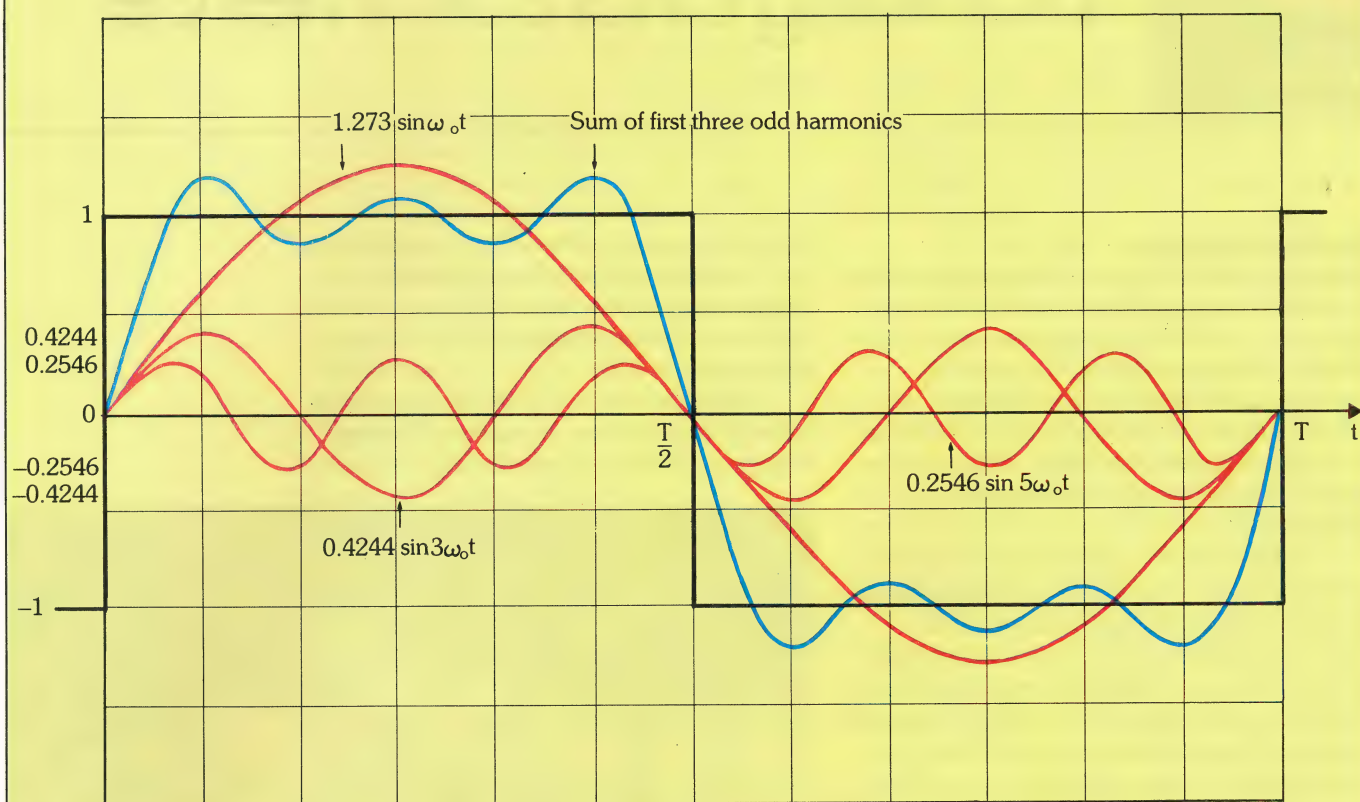
4. Fourier analysis of a square wave, suffers from the Gibbs phenomenon where the wave changes suddenly and the approximation is not as accurate.

red in *figure 4* and the sum of these three terms is shown in blue, which is an approximation, albeit rather poor, to the original square wave.

However, if we increase the number of terms in the series, the approximation will get closer and closer to the square wave, particularly in the flat regions at the top and the bottom. Where the wave changes suddenly from positive to negative at t = 0 and T, or from negative to positive at t = T/2, the approximation, unfortunately, is not so accurate. This problem, known as the **Gibbs phenomenon,** occurs at places in any wave where the magnitude changes suddenly. Apart from this, the first few terms of the Fourier series give a quite accurate approximation to any waveform; the more terms that are included the closer the approximation.

Use of Fourier series

Since we can analyse any network for a sinusoidal input voltage, we may break up any non-sinusoidal repetitive voltage into its Fourier components, analyse the network for each component – obtaining the output current

flowing at each harmonic frequency – and then add these together to give the total output current.

Another application we have met is a non-linear power amplifier using a tuned circuit to give high power gain at a particular frequency. The non-sinusoidal current from such a class C amplifier may be analysed into its Fourier components and the response of the tuned circuit determined at each frequency. □

New technology in banking and commerce

Introduction

It seems hard to believe that little over ten years ago the idea of using a piece of plastic instead of cash or cheques for purchases and banking would have seemed more at home in a science fiction novel than in the high street. However the age of the plastic card has now well and truly arrived.

Of course, the card in its many and varied forms is only the most visible sign of a worldwide revolution in the financial world. Computers and computer related devices have considerably increased the reliability and efficiency of many shops and banks with applications ranging from simple credit checks and stock control to high speed international banking services.

While it is usual to look to the United States as the technology leaders, it is surprising to learn that the U.K. was host to the first generation of 'through the wall' cash dispensers, and that the machine itself was developed by the British arm of the American computer giant, IBM.

Whilst offices and manufacturing industry have been able to take their time over the implementation of new technology products, banks and other institutions involved in large scale financial transactions have been forced to accept it out of necessity. The reason for this is that the volume of financial traffic has increased enormously over the years, until now the London clearing banks process about 2000 million cheques and credit transfers a year.

Until recently, all of these transactions were recorded on paper and processed either by hand or by slow electromechanical devices. However, the old manual systems have proved totally inadequate to cope with the huge increase. The response of the new technology to develop a faster, more efficient, less labour intensive system of handling transactions has been given the name **electronic payment services** in the U.K. or **electronic funds transfer** (EFT) as it is known in the U.S.

Banking in the eighties has not been without its problems, however. Perhaps the most important issue for the

international banking community, the need to be able to communicate in a common language, has yet to be resolved. In computing, this amounts to setting up common communications standards for computers and their peripherals. It might sound easy but, in practice, the issue has become a veritable minefield, with powerful lobbying blocks each convinced that their own ideas should succeed.

To add to these problems, rival manufacturers complicate the situation by

Above: Midland Bank international section. New technology has revolutionized financial dealings at all levels, with computerized processing of transactions and instant access to a vast range of constantly updated information.

Science Photo Library/Jerry Mason

their efforts in introducing a so called 'de facto' standard, by flooding the market with one type of machine (which may even use a system contrary to the prevailing standard adopted by the country in which it is used). This was not such a problem until the size of the computers used in financial operations began to decrease.

Ten years ago, anything other than a mainframe, or at the very least a minicomputer, would not have been powerful enough to support a financial system. Today, however, with microcomputers as powerful as yesterday's mainframes, there is a proliferation of different machines taking the concept of financial transactions out of the computer room and onto the office desk. Microcomputers have also put the power of financial analysis into the hands of people who would otherwise have had to rely on accountants or specialists. The effect of this on financial institutions has not yet become clear as the new technology has not yet totally penetrated this sphere of activity.

Of course, computers have been in use by financial institutions for some time now. They were originally introduced to manipulate accounts and payments, both within and between banks. A standard code of identification for banks on cheques was developed and a special set of symbols for magnetic and optical character recognition has been agreed, to help convert data about transactions into a machine readable form.

Later, those organisations and companies with significant financial dealings were able to link with the banks to provide services such as payments of salaries, share dividends and tax deductions. Standing orders became commonplace and statements were then computerised.

The electronic transfer of money is now being taken a stage further with the installation of automated 'through the wall' teller machines. These machines, usually sited in banks, enable customers to use a debit card (with a magnetic strip identifying the cardholder) to obtain cash from their account. Security is maintained by each cardholder having a personal identity number or PIN to access the system.

The plastic card

NCR, one of the most successful financial computing companies, and the leading supplier of auto-teller 'through the wall' cash dispensers, realised the potential of what they describe as 'the plastic card revolution' and performed an extensive market survey.

Chief among the company's findings was that about 90% of all routine personal cash withdrawals would be made through auto-teller machines by 1985.

By the end of the decade, NCR also expects to see half of all retail sales made by plastic card, and an initiative made by employers to use cards instead of pay packets. This could be accomplished by encoding an employee's salary onto a card for transfer, or using auto-tellers at the place of work.

What makes the card so popular? The answer lies in its advantages over traditional forms of handling money. To begin with, the card, being plastic, is very tough and far outlasts both banknotes and cheques in its durability and flexibility.

It is also more secure. A cardholder needs only a password or number to validate the card's use and this can be cancelled with a single phone call, which is not possible with a five pound note.

The individual code and a great deal of other useful information is stored on the dark brown strip on the back of the card, which is like a piece of magnetic storage tape. The card is magnetically coded in a digital form which can be read and understood by the auto-teller machine.

The embossing of the cardholder's name and expiry date is purely cosmetic as far as the machine is concerned. This information was originally designed for printing details on a hand operated receipt dispenser – these are now being replaced by compact, desk-top machines which act like auto-tellers.

Both the 'through the wall' and desk-top machines must be connected to a large host computer, which holds all records and acts as a terminus for data received from a number of auto-teller machines. This host may also be part of a larger network, connecting branches throughout the country and/or international banks.

Midland bank, for example, is already setting up a system which enables U.K. cardholders to draw cash from machines in France and Spain.

Auto-teller machines have become more flexible and can now offer facilities such as statements, cheque book ordering, depositing, bill payments and general information about the bank. In the U.S., machines are now being introduced which offer loan arrangement facilities, which can be concluded on the spot.

Payment by card

Payment by card is gaining increased acceptance both in Europe and the U.S. Cards are used in large stores and hypermarkets which allow customers to pay for anything in the store, from groceries to furniture.

The next few years will probably see a period of consolidation for major retailers where off-line (stand alone) or on-line (networked) computer systems will be increasingly used not only for credit card

The Research House/British Telecom

Left: The City Business System is a prime example of specialized equipment designed to meet the exacting needs of currency and commodity dealers. A combined telephone, telex and computer terminal, the system can store 5,000 pages of information, access data from other computers, and cater for over 1,000 telephone lines and over 500 dealer consoles.

NCR's survey conclusions predict the widespread use of remote auto-tellers in places of work, airports and railway stations. The company has just installed a trial system at Glasgow railway station which enables payment for rail tickets by card.

The idea that cards may replace wage packets depends on the acceptance of these machines outside banks. In principle, it is more economic for employers to pay direct into bank accounts. If an auto-teller were available at the workplace, then employees would be able to draw cash there, so mollifying those critics who complain of having to walk to the bank. At present, only around half of British workers are paid by direct bank order so this idea still has some ground to make up.

transactions but also for daily claims files, stock control and up to the minute 'hot lists' of lost or stolen cards.

It is the security inherent in the system, together with the savings on paperwork, which appeals to business, and with the response time between a card being lost or stolen and notification of the store continuing to shrink, card fraud will become less attractive.

In the U.K., both the Army and Navy and Bentalls chains are now using a system along these lines for processing Barclaycard and Access transactions, and have replaced credit card vouchers with their own sales slips. The system also processes the daily deliveries of magnetic tape updates, thereby keeping the stores up to date with 'hot list' information.

1. Example of a European standard bar code, used for product and price identification of retail goods. The arrangement of bars and spaces corresponds to a digital code that can be read by an optical scanner.
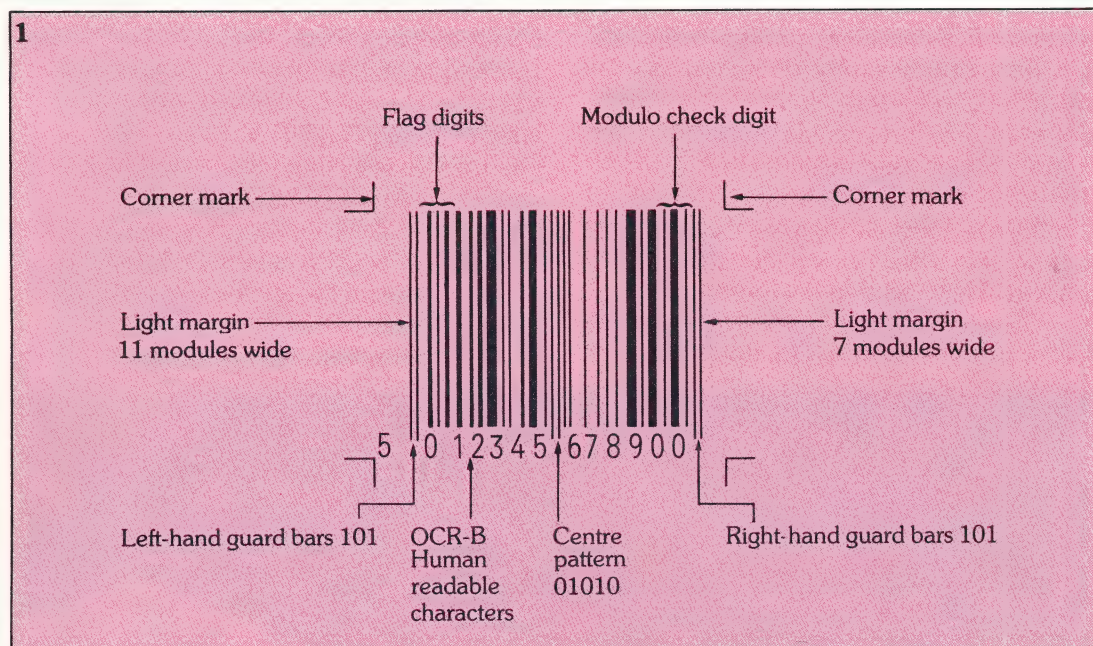
Credit control is also being taken one step further by the Army and Navy chain which is using a satellite linking system to verify the creditworthiness of American Express cards issued in the U.S. This system links sales terminals to the credit company's Arizona based authorisation centre in seconds.

The benefits of using a card for retail and credit operations extend beyond security as it offers potential savings for all parties concerned. From the banks or credit houses point of view, the cost of handling the huge volume of cheques has been dramatically reduced. To give some idea of this volume it has been estimated that the number of cheques written in the U.K. each day would build a stack a little higher than Mount Everest. Cash handling is also reduced – it is no longer necessary to keep large amounts of cash lying around in tills and bank drawers.

Until now, the use of cards has not really reduced the amount of paperwork involved in business transactions. However, as the cost effectiveness of purely electronic systems continues to improve, it can only be a matter of time before the effect of these systems really begins to be felt.

In France, a trial system by Credit Agricole has proved so successful that a full implementation programme for a chain of hypermarkets is underway. Credit

Agricole, one of the world's largest banks, now employs a system which allows customers to use their bank cards at the POS terminals in the store. (POS or **point-of-sale terminals** is the name given to the computerised terminals at supermarket check-outs and department store counters.) After a simple checking procedure, where the card is magnetically read by the till, the customer enters his user number and the amount of the purchase is automatically deducted from his bank account.

In the U.S., it is possible to shop using a home computer and a teletext-type catalogue linked to the computers of some large stores.

The EAN system of bar codes

Bar code technology, though present to some extent, is still in the early stages of development and acceptance and so it is worth mentioning some of the hybrid systems in use today.

One of the nightmares of any large store is stock control. Keeping up-to-date information on which lines are running out, when shelves need restocking and when re-ordering is necessary has been aided by the introduction of the **European article numbering** (EAN) system of **bar codes**.

The bar code system is an example of how an international agreement can introduce an effective standard, which is

easier for POS terminal manufacturers, as they have only to produce one type of machine, and for shop owners, who are free to choose between different manufacturers' offerings.

The code is a simple series of thick and thin bars representing, in digital form, a string of numbers which identify the product. This is shown in *figure 1*.

The code can be read by either a light pen or a low power laser by the POS

customer payment (apart from cash) is still by cheque, and POS terminals have now been developed, by NCR for example, which can read and even fill out customers' cheques, to save time. Such machines read cheque code information (another standard) which is printed in magnetic ink, and even fill out the name of the store and amount, leaving the customer only to sign for the goods.

There are also microprocessor

Left: An alternative to the bar code system is the use of a magnetic strip which can be 'read' by a wand (rather like the head of a tape recorder). The strip can contain a variety of coded information which can be fed into a central system for use in sales records and stocks control. (Photo: IBM).

terminal. Networked POS terminals can then use this information to automatically price goods (removing the need for labelling); record the level of sales of particular products and hence update stock control data; alert staff to the need for shelf restocking. This information can then be fed to a host computer (either in the store or at some central remote location) for analyses of buying trends and forward planning.

As well as increasing efficiency in the store, this kind of technology improves the life of shoppers as the chance of pricing errors and the time taken to process each customer is reduced. The likelihood of the store running out of popular items also decreases.

The most popular method of

controlled stand alone POS terminals which take the price per weight for items such as fruit and vegetables and print out a pricing label on the spot; some cash registers can also be programmed with price details and data for bar code reading.

Networking to improve efficiency
Stand alone terminals are very adaptable; they can be linked to bar code reader and data tape machines, and are likely to remain in widespread use in small shops and organisations. But the future for any organisation which either has multiple sites or needs to assimilate a lot of data quickly, lies with **networking**.

A network is simply a method of linking a number of remote machines to a central host, or hosts. The gathered

information can then be processed and new data communicated to the remote sites simultaneously.

Networking has two major benefits: first, it provides fast communications; second the expensive resources, such as storage and printing facilities, are shared by a number of locations, hence dramatically reducing system costs.

A number of different configurations are in popular use: branching, where levels or hierarchies of different machines are used; ring networks, where every device is connected to part of a continuous loop; and star networks, where each device is connected to a central station. The principles behind networking are discussed in detail in *Computers and Society 2* and a later chapter in the *Communications* series.

In practice, large networks comprising combinations of these three types are common. Typically, the terminals, which could be auto-tellers, POS cash registers or microcomputers, communicate with a mini or mainframe computer which handles routine requests for calculations and data, and itself provides multiple access to large storage devices containing files of other information, such as financial forcasts and exchange rates.

Network communications may either be built into the various elements in the system or may be handled by a separate machine. Digital data is transmitted around the network via coaxial or twisted pair cabling if sites are within the same building, or over leased telephone lines if communication is between remote sites. The introduction of fibre optic cabling promises voice and data transmission down a single line, and improved data transfer rates.

Specialised switching devices, packet switches or PABXs (for private automatic branch exchange), handle communications between sites and provide security encryption, data checking and protocol matching (called **handshaking**).

Standards

This all sounds relatively simple, and indeed it would be if the different machines involved spoke the same language. In practice, however, the isolated introduction of different networks each with their own communications protocols has complicated the issue. If any consistent standard is to emerge, it looks more likely to come from the commercial domination of a market sector, rather than from direct legislation.

The banking and financial market is dominated by three American manufacturers – IBM, Burroughs and NCR – and a number of smaller companies manufacture compatible equipment.

The software industry has also been quick to react to this standardisation problem by providing protocol conversion and emulation packages – these make one manufacturer's terminal, for example, appear to belong to a second manufacturer's network by changing its language into a form which the network can understand.

In Britain there are two standardised banking data networks, each with their own approach to the standards issue. The most successful to date is **SWIFT** The Society for Worldwide Interbank Financial Telecommunications.

The system is ten years old and has been in operation for six of these. Initially, it linked 500 banks in fifteen member countries and it has now grown into a fully international communications system which currently links some 1100 members in 53 countries. Each day, approximately 350,000 transactions are carried out, spanning Europe, the Americas, the Far East, Australasia and China, using leased national telephone lines and satellite links. SWIFT handles foreign exchange confirmations, credit transfers, statements and queries.

The original concept was to provide a specialised service to banks in Europe and North America using common standards. SWIFT is not a bank itself, and does not provide its subscribers with communications facilities. Instead, members have been encouraged to adopt common protocols and languages for financial transactions. SWIFT is now a widely accepted system which offers a large user base.

After consultations with proposed members, a common language was

derived by standardising data formats using the minimum amount of native language – this also benefited the system by reducing the amount of superfluous data sent from one site to another.

Security in such a system is extremely important and SWIFT provides this through a sophisticated series of data encryption codes. These are changed at random intervals, thereby making it impossible for one member bank to gain access to information from another member without authority. Even the SWIFT organisation, which monitors the network's performance, has no way to interpret the information being sent – it can only check that information is sent and received without distortion.

Members gain access to the system via a specialised terminal known as the **SWIFT interface device**. This operates completely independently of the banks' other computerised equipment (another aspect of security) and is available with specialised software developed by SWIFT. This strategy ensures the banks' freedom to choose any particular course of equipment purchase and internal services arrangements without affecting its ability to use the network.

A second generation version of the system, **SWIFT II**, is now in the final stages of development. The new system will enable members to transmit on a single transaction basis, rather than the present method where data is transmitted in convenient blocks.

The only restrictions to membership are that the bank concerned must process a certain minimum value or number of transactions and must also have agreement from its national telecommunications carrier. The only major Westernised banking centre not yet covered to some extent by SWIFT is the Middle East.

CHAPS

The second of the two standardised banking networks is a new British networking system, **CHAPS** (Clearing House Automated Payment System). CHAPS was set up by a consortium of banks seeking to shorten the length of time taken to clear large cash transactions. The traditional method – sending a messenger

from bank to bank – became so uneconomical that it had contracted to cover only London, and then only for amounts greater than £10,000.

The network finally agreed upon is based on a 'virtual' loop using British Telecom's X.25 **packet switching service** (PSS). The hardware and software is manufactured by ICL and Tandem, and covers the interface between the clearing banks' existing computer equipment and the network.

The hardware is responsible only for maintaining the CHAPS service, but software provides the link into the bank's own payment system, converting data into mutually acceptable forms. Each node in the network is served by a Tandem minicomputer which handles each bank's operations independently. In theory, the cost of each minicomputer is covered by the saving made on other operations, however, the system does require that each bank maintains a fairly high volume of transactions for it to be cost effective.

The result of the system is that customers may now demand same day payments, which is particularly important for large transactions, instead of the usual three day clearing time. Each operation is added to a list at the node, the data is then coded before transmission to the other banks in the system. At the receiving node, identification of requests for payment or confirmation intended for its use is achieved by a set of address characters at the beginning of each message. Those requests intended for other banks are rejected before the information is decoded.

Despite the difference of approach between SWIFT and CHAPS, these examples help to illustrate how the financial community is attempting to keep networking as open as possible, i.e. they are trying to move away from dependence on any one manufacturer.

Manufacturers are attempting to counter this by providing widespread networking options. IBM, for example, has recently announced its intention to provide a system based on a token ring concept using its established systems network architecture, and the U.S. telecommunications giant, AT&T is preparing its extensive telephone service

for use as a network.

Financial packages and services

So far, banks have been rather sporadic in their adoption of the micro – some having no more than a few whilst others, such as Citibank, having more than 200. The trend towards their use has its roots with machines like the Apple II and VisiCalc software. Now, with the success of IBM's Personal Computer (PC) and its variants, software like Lotus 1-2-3 and its successor Symphony will provide the micro user with the power to rival mainframes for analysis, forcasting, rate of return and stock analysis.

Moreover, packages developed for specific financial applications such as foreign exchange, allowing a banker to take advantage of short term price discrepancies (known as arbitrage), will further distribute the concentration of expertise away from the data centre.

Consultancies, like the London based Personal Computers, are now marketing complete financial systems built around micros, commonly the IBM PC. The appeal of such systems is obvious; traders and analysts can now run sophisticated stock analysis from just about any office for a fraction of the cost of a mainframe based system.

Similarly, in large organisations, individual members are freed from the need to use large scale systems when performing their duties, speeding their reaction time to events.

If fitted with a micro/mainframe link, the user can also download information from such companies as Datastream (the City-based information provider), for data on companies which can then be analysed on the spot.

Large databases now exist in the banks and city finance houses which are used for financial modelling to provide an aid to decision making – these institutions have an almost unquenchable thirst for new up-to-date information. This has led to a whole new industry springing up, where companies sell information of stock movements, company performance and share deals.

Among the most popular forms is to provide this information on a wire service, similar to the way news is circulated to the world press, but the trend is towards teletext type services which provide subscribers with an 'on demand' system.

In Britain, Extel offers U.K. subscribers a range of services ranging from news teleprinting to a securities database, and investment portfolio management service and two systems for dividend schedules.

The British Stock Exchange itself commissioned a study of financial databases in 1982, and has agreed to fund a multi-million pound project to link financial institutions via British Telecom's X.25 packet switching system. The Stock Exchange has been running a service called **Talisman** since 1979. This service uses IBM 4341 medium scale mainframes to connect stock jobbers to stockbrokers.

Below: Another view of the City Business System. Notice how operations are controlled by fingertip touch of labelled 'keys' which appear on a VDU. The touching action is detected by a grid of infra-red beams which run over the surface of the screen.

The Research House/British Telecom

The new Talisman system will record settlements of deals through the use of Tandem minicomputers in conjunction with IBM personal computers.

The first phase of the project will only effect the gilt market but it is intended that Talisman will replace paper share certificates and the whole stock transfer system with a system known as **BETA** (Book Entry Transfer Administration).

One effect of computerising this area of the financial world will be to open the area to non-city based organisations to carry out stock transactions – banks, building societies and solicitors being amongst the most obvious.

Fast communications through computerised databases also help banks, which can subscribe to services covering the movement of currencies' to remain competitive by setting exchange rates and interest rates based on up to the minute information.

The stock market as a whole appears to favour these services and trends movements among the listed companies offering these services show a 40-60% share price improvement.

Once again it is the ability to feed information into a large network like telex, teletext or leased telecommunications line, which makes these operations feasible, together with the ease with which computers can be configured to handle this data.

Looking to the future

As banks and other financial institutions move towards the concept of a cashless society, so the nature and appearance of the buildings which house them will change. Experimental sites which take advantage of the new developments are already springing up.

The traditional 'glasshouse' appearance will disappear as desks with individual computer terminals replace counters and screens. This approach has been tried by the Peterborough Building Society. The interior of one of its branches has been completely redesigned and a series of desk-top micros linked to a 'master' micro have been installed.

The Society reports considerable success – with the elimination of the imposing bullet proof screens making communication between customer and clerk a more civilised and private affair. The new office is now so popular that the Society's directors have been prompted to consider extending this successful policy to other sites.

The proliferation of microcomputers in both small and large organisations as well as the banks will enable communication without the need for vast amounts of paperwork. Information such as monthly statements will be sent directly, possibly via a modem link, from bank to customer. Monthly accounts will be sent from client to bank, loans will be organised, funds transferred and payments made without either the need to move a penny or to write anything down.

One problem with today's microcomputers is that they offer a wide range of machine compatibility (and if they don't, software emulation packages can easily be written for them), and the question of data security is increasingly important. Stories about computer fraud, where funds are siphoned off to Swiss bank accounts or information regarding business competitors is used for financial gain, are becoming more common.

This is a very serious problem and in many countries legislation is only now being drafted to cover such things.

Conclusion

The commercial and financial worlds are poised for a series of fairly rapid transformations as computer technology opens the door for more efficient operations. However, although the industry was one of the first to take the computer seriously, progress could be hampered by a lack of standards, particularly in networking. This could hinder financial services from achieving the kind of efficiencies that even current technology promises.

The cashless society is now on our doorstep, yet many of the key decisions about the form it will take have yet to be made. There is no doubt, though, that computer operations at the counter, be they at the bank, building society, or store, will mean a faster and more efficient response for the customer.

ELECTRICAL TECHNOLOGY
Fourier spectra and integral

In the previous *Basic Theory Refresher*, we saw that any periodic wave may be represented by the sum of a number of sine and cosine waves. The frequency of the lowest member of this series is given by the reciprocal of the period of the wave considered, and all other members of the series have frequencies which are harmonic multiples of the fundamental frequency. We also saw that the series may be infinite in extent, in which case a satisfactory approximation to the given function may be obtained by using a finite number of the early terms of the two series.

We can now go on to show that these two series, the sine and cosine sequences, may be written as a single series. Consider the two members of the sequences at, say, the second harmonic frequency. These both have amplitudes:

component has an amplitude, given by the value of c, and a phase angle, given by the value of ϕ. These two parameters of any wave may be represented by a graph of the magnitude and phase of each component, termed the **spectrum** of the wave.

We know from the previous *Basic Theory Refresher* that the amplitude of the spectrum of a triangular wave is independent of the point in the wave which we choose as t = 0; the phase angle, however, does depend on this arbitrary choice. For example, if we consider the third harmonic we find for the first series that:
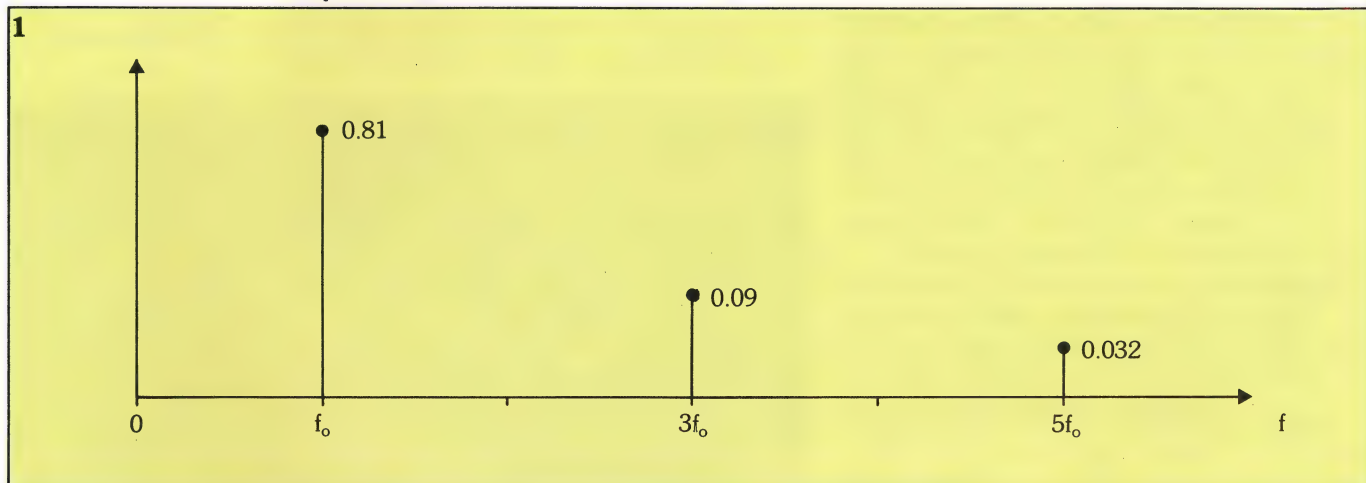
$$a_3 = 0 \; ; \; b_3 = -0.09$$

and hence:

$$c_3 = 0.09 \; ; \; \phi = 180°$$

Again, for the second series:

$$a_3 = 0.09 \; ; \; b_3 = 0$$

and hence:

1. Amplitude spectrum of triangular wave, where $\omega_0 = 2\omega f_0$.

$$a_2 \cos 2\omega_o t + b_2 \sin 2\omega_o t$$

which may be rewritten using standard trigonometric relationships as:

$$c_2 \cos (2\omega_o t + \phi_2)$$

where:

$$c_2 = \sqrt{a_2^2 + b_2^2}$$

and:

$$\tan \phi_2 = \frac{a_2}{b_2}$$

The Fourier series for a function f(t) may therefore be written:

$$\begin{aligned} f(t) = \; & c_o + c_1 \cos (\omega_o t + \phi_1) \\ & + c_2 \cos (2\omega_o t + \phi_2) \\ & + c_3 \cos (3\omega_o t + \phi_3) + \ldots \end{aligned}$$

where $c_o = a_o$. The other values of c and ϕ are given by similar expressions as those given for c_2 and ϕ_2 above.

Fourier spectrum
We can see from this, that each frequency

$$c_3 = 0.09 \; ; \; \phi_3 = 90°$$

The amplitude spectrum, therefore, is independent of the arbitrary choice of the instant at which we choose t = 0, and is thus a characteristic of the given wave.

The amplitude spectrum of the triangular wave discussed in the previous *Basic Theory Refresher*, where $\omega_o = 2\pi f_o$, is shown in *figure 1*.

Fourier integral
If we know that a periodic wave can be represented by means of a sequence of sine waves at multiples of a fundamental frequency, is there any way of respresenting a non-periodic wave? The answer to this question is that a non-periodic waveform can be represented in this way, however, instead of a sequence of harmonic frequencies, we have a set of continuous frequencies spread from zero frequency up to very high frequencies (in

2. Pulse waveforms and the related amplitude spectra.
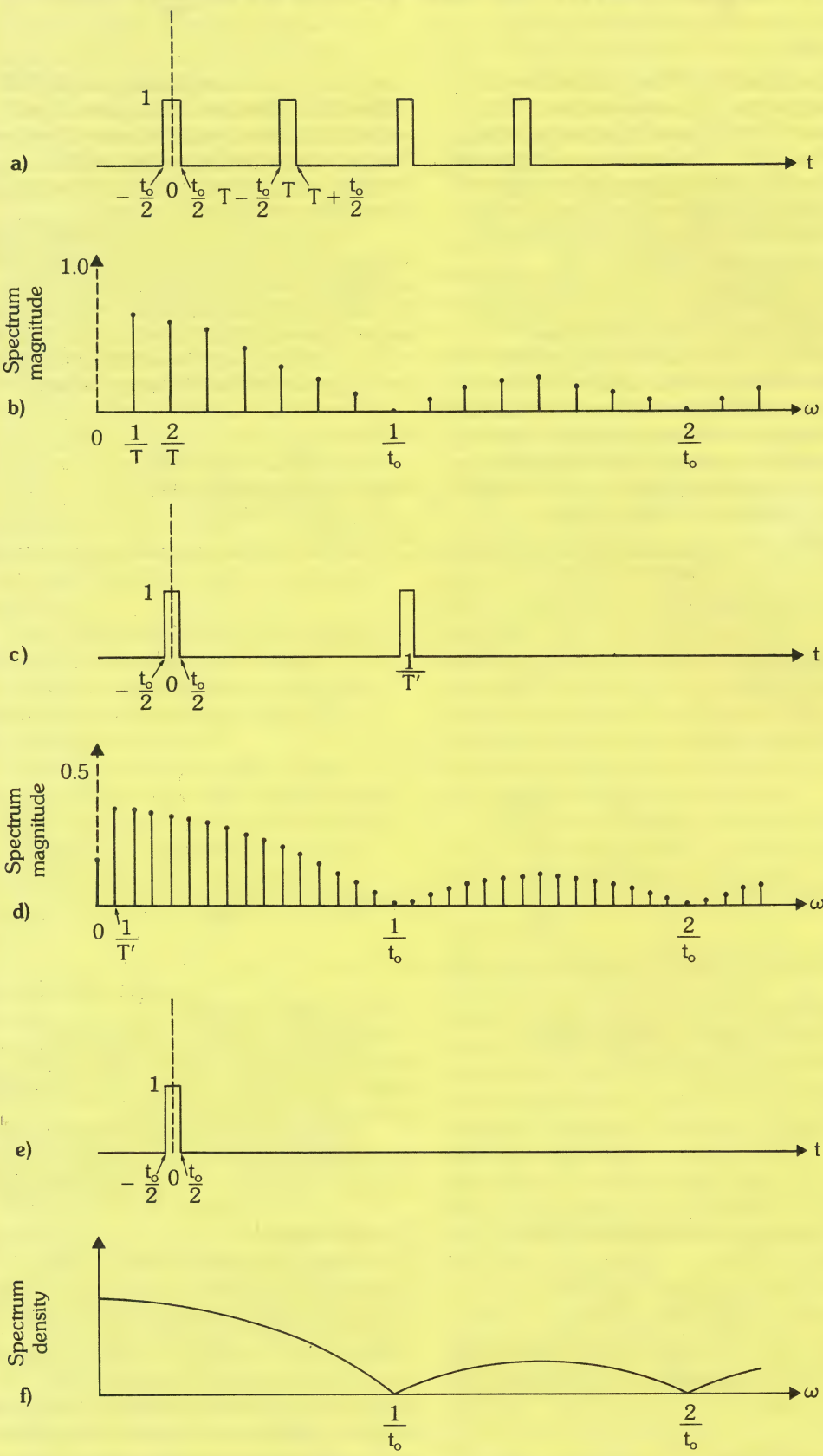
theory, to infinite frequency).

How can this be derived? Consider the Fourier series for the short pulse, of magnitude 1 and of duration t_o, which repeats every T seconds as shown in *figure 2a*. This has a series given by:

$$f(t) = a_o + a_1 \cos \omega_o t + a_2 \cos 2\omega_o t + \ldots\ldots$$

where:

$$\omega_o = \frac{1}{T}$$

and:

$$a_o = \omega_o t_o$$

$$a_1 = \frac{\sin \pi \omega_o t_o}{\pi \omega_o t_o}$$

$$a_2 = \frac{\sin 2\pi\omega_o t_o}{2\pi\omega_o t_o}$$

and so on, and is shown by the spectrum in *figure 2b*.

If the length of the pulse t_o remains unchanged, but the period of the wave increases from T to T′ (where T′ is approximately double T), then the values of the spectrum components will be given by the above expressions where ω_o is replaced by ω'_o

($= 1/T′$).

This waveform and amplitude spectrum are shown in *figures 2c* and *2d*. We can see that as the period between the pulses increases from T to T′, the interval between the consecutive components of the amplitude spectrum decreases from $1/T$ to $1/T′$.

The other point to notice is that the magnitude of the frequency components in both *figures 2b* and *2d* decreases steadily to an angular frequency, ω, of $1/t_o$, and that thereafter it increases again, falling to zero at $2/t_o$, $3/t_o$, etc. We can also see that the magnitudes of the spectral lines in *figure 2d* are about half those in *figure 2b*.

If we continue to increase the period between the pulses, we should expect that the intervals between the components of the amplitude spectrum will become shorter and shorter. Ultimately, what will remain is a waveform consisting of only a single pulse centred at time t = 0. This will have a spectrum in which all the components are tightly packed together to form a continuous spectrum as shown in *figures 2e* and *2f*. Note also that since the amplitude of the lines decreases as T increases, the magnitude of the various lines cannot be plotted when we reach the limiting case of a single pulse. Instead, the spectral density (i.e. the density of the lines in a very small interval of frequency) is plotted.

In order to give all the information which is contained in the orginal waveform we should also plot the **phase spectrum** of the wave. However, the amplitude spectrum is more important, particularly when dealing with sound waveforms as the ear is almost completely insensitive to variations of phase.

Summary

Any waveform which is represented as a function of time may, alternatively, be described by its amplitude and phase spectrum given as a function of frequency. This spectrum consists of either a number of discrete components where a periodic waveform is considered, or a continuous range of components for a non-periodic waveform.

It is thus possible to use the methods of analysis of networks for sinusoidal input voltages on each component of the spectrum, and then to add these at output. □

Below: waveform analysis plays a part in both the design and testing of new electronic equipment. Here, an IBM hard disk drive undergoes laboratory tests.

Satellite communications

Introduction

As we have seen, the twin problems of communications are, first, to encode information into a form suitable for transmission and, second, to decode that information at the receiver so that it may be readily understood.

The survey of communications methods so far has covered telephone communications of audio waveforms,

Table 1
Information able to be transmitted via satellite

Analogue	Digital
Speech, music	Digitised speech or music
Video	Digitised video
Facsimile	Digital facsimile
	Teletype or telex
	Computer data

Below: earth station aerials, of the type used at Goonhilly and Hadley.

The Research House/British Telecom

1. Essential elements of a satellite communications system.

Labels in figure: Sunlight · Satellite · Satellite orbit · Solar Panel · Antenna · Up-link · Down-link · Earth station 1 · Earth station 2 · Earth
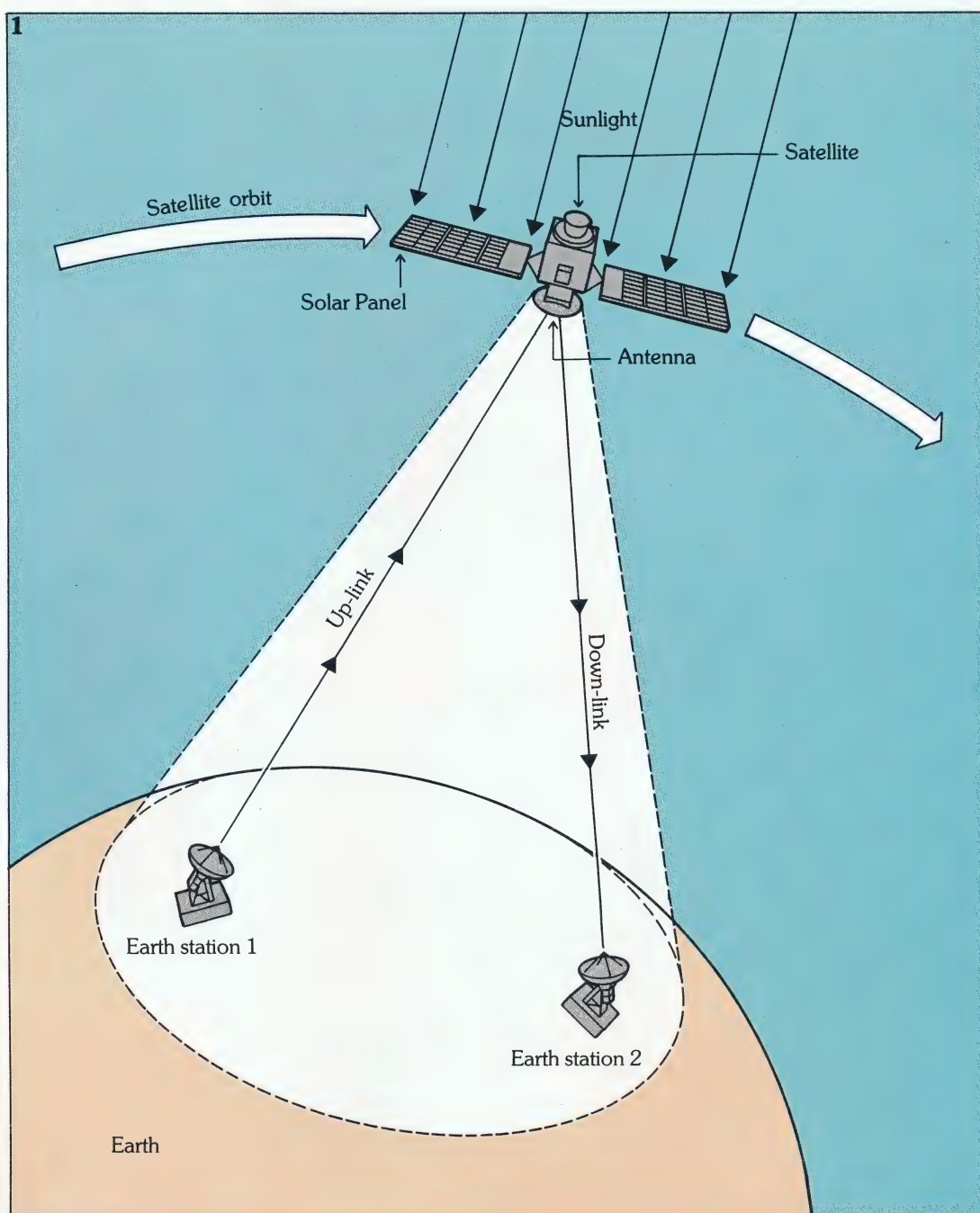
radio and television, and the transmission of information via teletype, telex and facsimile. The methods used to encode this information – AM, double and single side band, frequency modulation (FM), PCM etc. – and the means for transmitting the encoded information, wire, cable optical fibre and electromagnetic radiation, have also been discussed.

The next two chapters will look satellite communications – the most modern and up-to-date method for conveying information from one point to another. It is capable of handling all those information types previously considered, in either analogue or digital form (*table 1*). This information must still be encoded before transmission. Satellite systems offer many advantages:

1) global coverage for all types of communications;
2) very high capacity for transmissions;
3) low power requirements;
4) low maintainance costs.

2

Computer data

Local telephone exchange

International exchange

Facsimile

Telex

Television

Microwave relay station

Microwave links ——→|

Microwave repeater stations

Earth station aerial

Satellite earth station
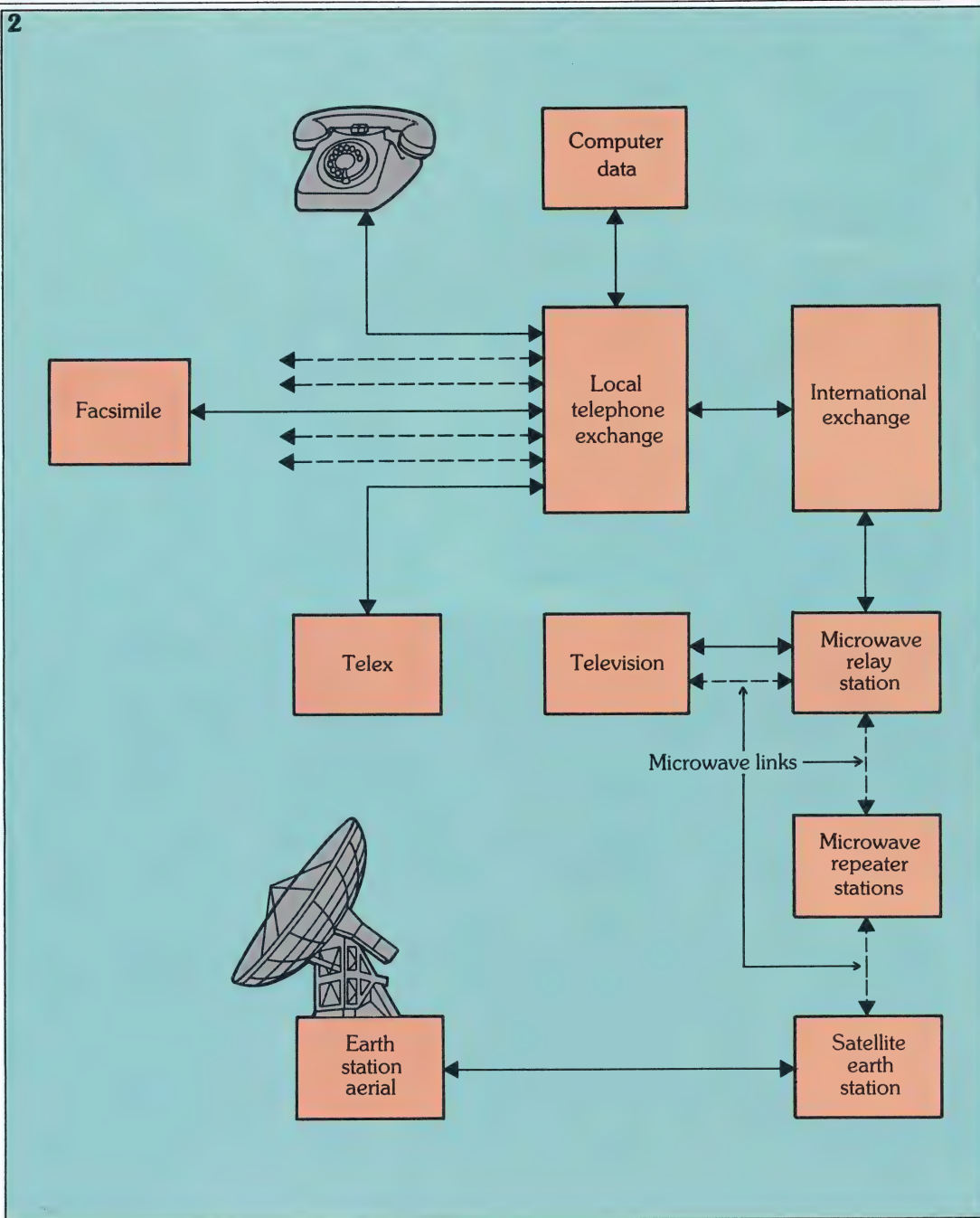
Systems overview

The essential elements of a satellite communications system are illustrated in *figure 1*. A satellite, powered by solar energy, is placed in orbit around the earth so that it is in **line-of-sight communications** with two or more **earth** or **ground stations**. Radio frequency energy containing communications information is aimed at the satellite using a **narrow-beam** transmitting aerial at the earth station; this communications link is known as the **up-link**.

The satellite receives the transmission from the ground and the **transponder** equipment which it carries reinforces the by now weak signal, relaying it to a second earth station via the **down-link**. In practice, the up-link and down-link use different radio frequencies.

The two earth stations both receive information from and feed information to a terrestial communications link with the use of more conventional cable or microwave

links. The communications network feeding a single earth station is shown in simplified form in *figure 2*.

Many earth stations are able to access a single satellite, passing information in both directions simultaneously. We will learn more about **multiple access**, as it is termed, and the techniques for simultaneous two-way traffic later in the chapter.

We already know that signals from many different sources can be multiplexed, forming groups and supergroups. Further multiplexing is performed at the earth station, but the feed to an earth station is not just one signal from one subscriber, but many hundreds of signals, multiplexed together as indicated in *figure 2*.

Historical perspective
The concept of communications satellites in permanent orbit around the earth was first proposed by Arthur C. Clarke (better known as the author of 2001: A Space Odyssey) in an article entitled *Extra-terrestial Relays*, published in *Wireless World* in October 1945. He envisaged three satellites placed in **geostationary**

3. Three geostationary satellites, equally spaced apart, at a distance of 36,000 km above the earth provide total global coverage.

3

Satellite 2 over the Pacific ocean (later to be INTELSAT II)

Satellite 3 over the Indian ocean
(later to be INTELSAT III)

120°

120°

120°

36,000 km above the equator

Satellite's orbital direction around the equator

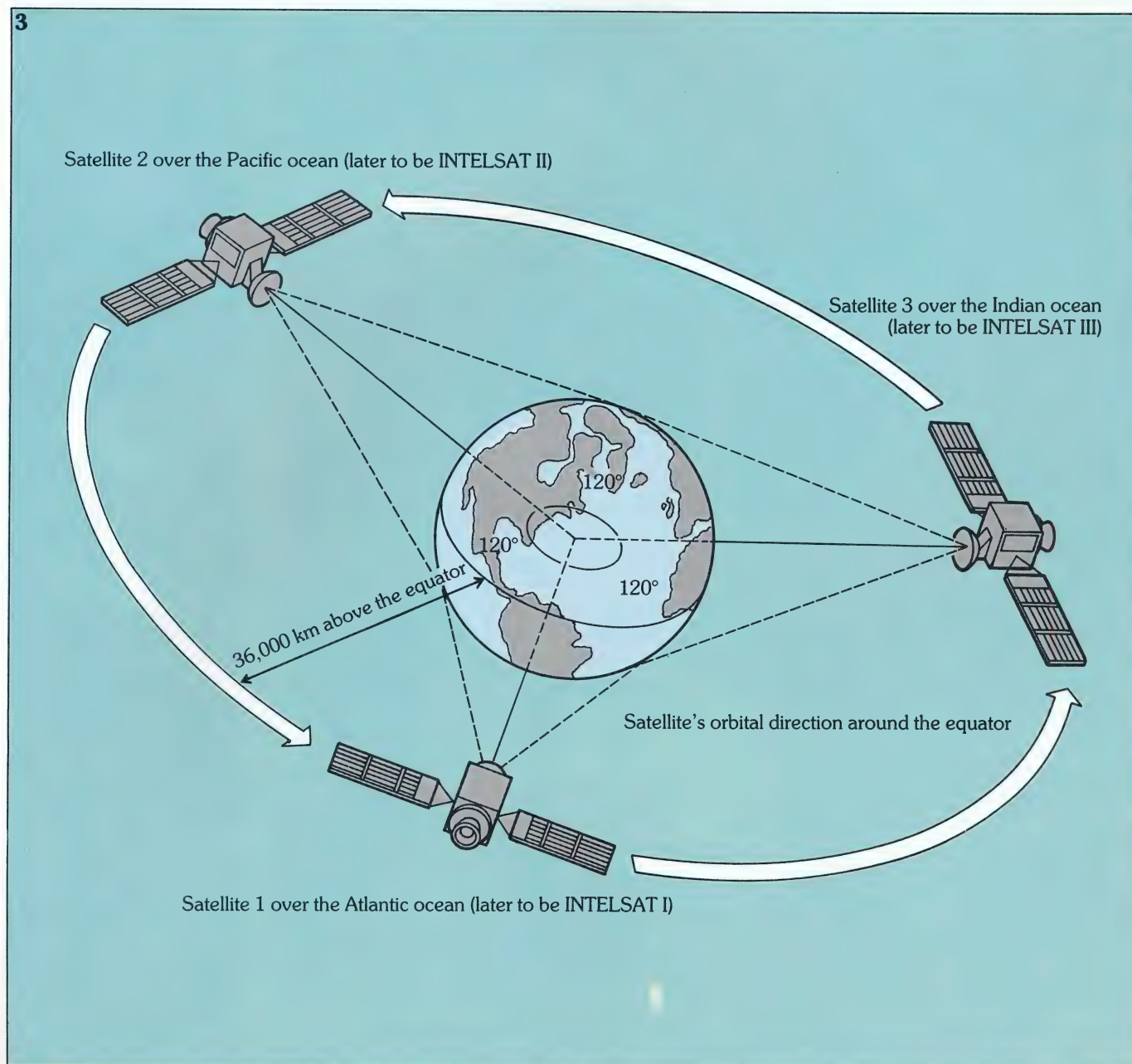Satellite 1 over the Atlantic ocean (later to be INTELSAT I)

Table 2
The INTELSAT system — a summary

INTELSAT	Date of launch	Weight at launch (kg)	Design life (years)	Capacity	Other characteristics
I	1965	68	1.5	240 telephone circuits *or* 1 television channel	No multiple access capability. TV transmission required relinquishment of voice and record traffic
II	1967	162	3	240 telephone circuits *or* 1 television channel	Introduced multipoint communications capability between earth stations
III	1968	293	5	1500 telephone circuits *or* 4 television channels; or combinations thereof	Expanded multipoint communications. Simultaneous transmission of all forms of communications
IV	1971	1415	7	4000 telephone circuits *or* 12 television channels	Multiple access and simultaneous transmission capabilities
IVA	1976	1481	7	6000 telephone circuits *plus* television. If only used for television then 20 channels	
V	1980	1864	7	12,000 telephone circuits *plus* 2 television channels	
VI	1986	13,740	10	33,000 telephone circuits *or* up to 144 television channels	

orbit about the equator at a distance of approximately 36,000 km above the earth, and equally spaced apart at 120° longitude as seen in *figure 3*. Between them, these three satellites would provide total coverage of the globe. The term geostationary (synonymous with **geosynchronous**) describes the orbit of a satellite which is travelling at such a speed as to remain at a fixed position above the earth's surface.

Clarke also made suggestions for the frequencies and satellite transmitter power that would be needed, and these proved remarkably accurate when the first working systems were commissioned.

Although written as science fact, and not as science fiction, Clarke's ideas went almost unnoticed until an American, J.R. Pierce, independently made similar proposals ten years later, in 1955. Operational satellites then followed as soon as rocket technology, orbital manouevring techniques, complex electronics, and the satellites themselves were developed.

Meanwhile, from 1945-1960,

experiments were carried out using the moon as a passive reflector of high frequency radio beams. Although some success was achieved (the U.S. Navy succeeded in establishing communications between the east coast of the continental United States and Hawaii), vast amounts of power had to be pumped at the moon in order to receive a detectable signal at the receiving station. These experiments culminated in the launch of Echo I in 1960. This 100 ft diameter balloon had a metallised skin, designed to act as a reflector of radio waves.

However, it had been realised for some time that an active satellite could reinforce the signal from the earth station, thereby requiring far less power at the transmitter, and in 1957 the first orbital satellite, Sputnik I, was launched.

Sputnik II and Explorer I followed in 1957 and 1958 respectively, then in 1962, the first satellite specifically designed for communications was launched – Telstar.

Telstar, however, was not launched into one of the orbits proposed by Clarke. Its orbit was quite low, between 320 and

480 km above the earth, and its orbital velocity was very high. As a result, it was only in sight of the earth station at Goonhilly Downs for 20 – 30 minutes on each pass. It was a considerable achievement to move the 1100 ton aerial quickly enough to track Telstar as it shot low across the sky.

The first geosynchronous satellite (SYNCOM I) was launched in 1963. It was followed by INTELSAT I (Early Bird) in 1965 and this formed the first link in the global network proposed by Arthur Clarke.

INTELSAT I was positioned over the Atlantic Ocean and handled traffic on the busiest communications link in the world. Two years later, INTELSAT II was launched over the Pacific Ocean, and in 1968 INTELSAT III was positioned over the Indian Ocean, thus completing the tripartite system of satellite communications envisaged by Clarke approximately twenty years before. For a summary of the INTELSAT system see *table 2*.

Satellite systems

The INTELSAT satellites that we have been discussing form part of a global network set up in 1964 to provide commercial satellite communications – the **I**nternational **Tel**ecommunications **Sat**ellite Organisation, of which Britain is a founder member.

Originally formed with eleven member nations, INTELSAT now comprises 109 partners, each investing and receiving revenues according to its use of the system (Britain is the second largest shareholder).

From the first satellite in 1965, the system has grown to encompass over thirteen satellites and more than 200 earth stations; each new satellite launched and each new earth station brought into commission being more sophisticated than its predecessors as the rapid advances in communications technology are incorporated.

Britain's first earth station was built in

Below: artist's impression of Intelsat V.

British Telecom

the early 1960s at Goonhilly Downs in Cornwall: its prime aim was to track the fast low-flying Telstar satellites. Goonhilly, operated by British Telecom, is now one of the largest and most sophisticated earth stations in the INTELSAT network: three of its four aerials support INTELSAT, while the fourth is allocated to the International Maritime Satellite communications service, INMARSAT.

Designed for satellite ship-to-shore communications, INMARSAT is operated through Maritime Communications Service (MCS) packages on INTELSAT V and MARECS satellites – a maritime version of the European Communications Satellite (ECS).

Both ECS and MARECS satellites are jointly built by a consortium of European manufacturers and are both launched via the European space Agency's Ariane launcher.

By the early 1970s it became clear that a second satellite earth station would be required to keep pace with the growth in satellite services, and so British Telecom's second earth station at Madley in Hereford was brought into commission in 1978.

The Madley I aerial points at the INTELSAT satellite over the Indian Ocean and calls from Britain to the Middle East, Africa, India, Far East and Australasia go via this aerial. Madley aerials II and III operate with other INTELSAT satellites and more are planned, one of which will operate with the ECS system.

The ECS system is operated by EUTELSAT, a consortium of European countries of which Britain is a member. It is designed to provide broad beam coverage of Europe and North Africa, with spot beams designated to particular areas of Europe. It has the same capacity as INTELSAT V and is also launched via Ariane.

In addition to linking the British telephone network to more than 80 countries world wide, British Telecom also provides special satellite services to television networks and cable TV operators. Two aerials, located in London, provide links to the U.S. via the INTELSAT V F4 (Flight 4) satellite, positioned over the Atlantic, and to continental Europe via the

ECS F1 satellite. These two terminals can handle up to eight TV channels simultaneously, receiving and transmitting programmes to France, Germany, Switzerland, Finland, Austria and Norway as well as the U.S. and Canada. A further four terminals are planned. Direct Broadcast Satellite (DBS) television will be covered in a later chapter.

In addition to the international satellites operated by INTELSAT, many other organisations and private companies, particularly in the U.S., have launched domestic satellites for point-to-point communications within the country of origin. These facilities are then leased to smaller enterprises requiring high grade communications services, but not wanting the expenditure of constructing and launching their own satellite. In the U.S., the Western Union Telegraph company, Radio Corporation of America (RCA) and U.S. Satellite Systems Inc. lease satellite services to such users as cable TV distributors, nationally based companies for computer data communications, and for teleconferencing.

National governments are also becoming involved in satellite projects (not least because the cost involved is usually too great for single companies to bear), especially those with large areas of rugged terrain which make normal communications over large distances extremely difficult.

SatStream
Through its International Business Services scheme, British Telecom International (BT's international and satellite services section) will be leasing satellite services to business via its SatStream service. SatStream uses specially designed small dish earth aerials to provide direct contact with North America or Europe.

The European link will become operational late in 1984, and will use the ECS F2 satellite; the North American path, opened in February 1984, is only operational to Toronto in Canada at present. Other areas of the North American continent will be brought into the service as satellite capacity comes on-stream.

TEST YOUR PROGRESS
with the
I.T.E.C. QUIZ

MICROPROCESSORS – 1

1. Microprocessor-based digital systems can be adapted to carry out one-off tasks, generally for less money than it would take to design a specific circuit.
True or False?

2. Which of the following devices does a microprocessor need to function as a microcomputer?
a RAM
b Interfaces
c Peripherals
d ROM
e Timer
f All of these

3. The operation of a microprocessor takes place in steps controlled by a clock or timer?
True or False?

4. Microprocessors are not programmable devices.
True or False?

5. What is used to transmit data to and from the I/O ports and the microprocessor in a system?
a A microwave link
b The monodirectional data bus
c The bidirectional data bus
d Wires
e All of these
f c and d

6. Processor operation is not cyclical.
True or False?

7. In a microcomputer, flags are raised by:
a The CPU
b The ALU
c The BBC
d The AGC
e None of these

8. Jumps can be used to make a loop.
True or False?

9. A microprocessor can make data transfers to and from other devices and within itself.
True or False?

BASIC REFRESHERS

1. The efficiency of a transformer is defined as:
a The ratio of the input power to the output power
b The ratio of the output voltage to the input voltage
c The ratio of the output power to the input power
d The ratio of the output current to the input current
e None of these

2. The input power to a transformer is equal to the output power plus losses.
True or False?

3. A lagging power factor will give a lower maximum efficiency for a transformer than one that has a unity power factor.
True or False?

4. An autotransformer:
a Is used in a motor-car
b Adjusts its output voltage automatically
c Can provide a variable secondary voltage
d Only has one winding
e a and b
f c and d

5. Jean Fourier showed that any repetitive wave can be expressed as the sum of a series of sine and cosine waves
True or False?

6. The series of sines and cosines in a Fourier analysis of a waveform:
a Will continue infinitely
b Will start at the fundamental frequency and contain all the harmonics
c Contains a constant term
d None of these
e All of these

7. The constant term in a Fourier series represents the steady DC component of the waveform.
True or False?

8. The frequency of the lowest member of a Fourier series is given by the integral of the period of the wave considered.
True or False?

Answers to last week's quiz

DIGITAL & SOLID STATE APPENDICES – 9	DIGITAL & SOLID STATE APPENDICES – 10	COMMUNICATIONS – 6
1 g	**1** a	**1** c
2 e	**2** True	**2** b
3 d	**3** False	**3** c
4 True	**4** a	**4** e
5 b	**5** False	**5** a
6 False		**6** g
		7 a

COMING IN PART 38

Communications 7 continues the first of two articles in our detailed look at **satellite communications**.

Microprocessors 2 considers **instruction codes**, **addresses** and **timing signals** in a microprocessor system.

Computers & Society 10 begins an in-depth look at the effects of **new technology in manufacturing industry**. Computer aided manufacture, process control, programmable logic controllers and CAD are all covered.

I.T.E.C.

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